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Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

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Observations and Data on a Promising Selection of the West Indian Cherry, *Malpighia Punicifolia L.*

F. Aróstegui, C. F. Asenjo, Ana I. Muñiz, and L. Alemañy[1]

INTRODUCTION

Fieldwork on the West Indian cherry, (*Malpighia punicifolia* L.) was started at the Agricultural Experiment Station in 1947. Since then two plantings comprising 400 trees have been under study at the Main Station in Río Piedras. During the years 1951, 1952, and 1953, 238 trees were planted at the Isabela Substation on a Coto clay soil.

The West Indian cherry or "acerola," as it is commonly called in Puerto Rico, has become a potential economic crop because of studies made by Asenjo and coworkers in 1945, which led to the discovery of the high ascorbic acid content of the juice of these cherries (1)[2] (4). Further work done by this group on cherries harvested at the Agricultural Experiment Station has confirmed their original observations (2), (3).

Santini (5) has recently reported that, besides ascorbic and dehydroascorbic acids, the only other acid present in the West Indian cherry in appreciable quantities is l-malic acid, which is not biologically active. He also has published a method for the determination of reducing and total sugars in the juice of this cherry (6).

DESCRIPTION OF THE GENUS *Malphigia*

The botanical literature on the genus *Malpighia* is rather limited. There are over 30 species in tropical and subtropical America. The genus was named in honor of Marcello Malpighi, an Italian botanist (1628–93).

Apparently some confusion has arisen in the description of two of the species namely, *M. punicifolia* and *M. glabra*. Similarity of botanical charac-

[1] Associate Horticulturist, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.; Head, Department of Biochemistry and Nutrition, School of Tropical Medicine, San Juan, P. R.; and Research Assistant in Nutrition and Research Assistant in Agronomy at the Agricultural Experiment Station, respectively.

The authors wish to express their appreciation to A. Riollano, R. Gandía-Caro, and R. García-Lugo for their assistance in this work at the Isabela Substation.

[2] Numbers in parentheses refer to Literature Cited, p. 56.

ters exists between the *M. punicifolia* of Linnaeus and *M. glabra* of Millspaugh, this probably being why two names are ascribed to the same species.

A good botanical description of *M. punicifolia* L. is given by Britton and Percy (7) and is repeated here for purposes of clarification. Our West Indian cherry selections correspond closely to this description, hence we believe our species to be *M. punicifolia* L.

Malpighia punicifolia, L. Sp. Pl. ed. 2,609. 1762.
M. punicifolia lancifolia Nds. Gen. Malp. 8. 1899,
M. punicifolia vulgaris Nds. Gen. Malp. 8. 1899,
M. punicifolia obovata Nds. Gen. Malp. 8. 1899.

A shrub or small tree. Leaves elliptic, oblong, or obovate, or narrowly oblanceolate, 2–7 cm. long, 0.8–4 cm. broad, obtuse, or rounded and often emarginate at the apex, acute or cuneate at the base, glabrous when mature, the petioles 1.5–4 mm. long; cymes sessile or short-peduncled, the branches usually pubescent; sepals ovate, 2.8–3 mm. long; pubescent; petals pink or violet, the larger ones up to 9 mm. long; drupes globose, ovoid, or subglobose, 1–1.6 cm. in diameter, scarlet. (*M. glabra* of Millspaugh, not of Linnaeus.)

Occasionally spontaneous after cultivation in Puerto Rico for its fruit; St. Croix; St. Thomas—St. Martin to Trinidad, Margarita, and Curacao, northern South America. *Cereza Colorada*. West Indian cherry, chereese.

VITAMIN C IN THE RIPE CHERRIES OF SELECTION B-17

Among the selections under study at our Station, No. B-17 seems to be a very promising one when such factors are considered as yield of fruit per acre, fruit size, yield of juice per fruit, and vitamin C content of juice.

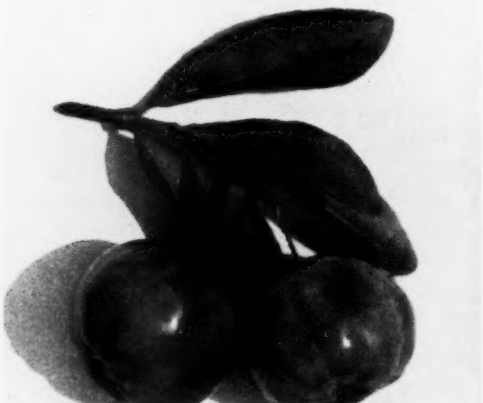

FIG 1.—Two fruits of clone B-17, West Indian cherry, *Malpighia punicifolia* L.

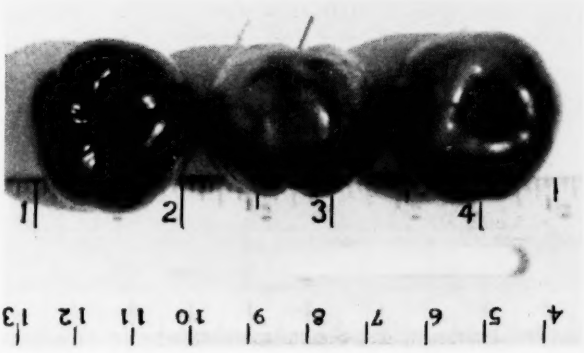

FIG. 2.—Ripe fruits of clone B-17, West Indian cherry, *Malpighia punicifolia* L. Note especially the shape and large size of these fruits.

The yield of fruit per acre can be estimated from the available data to range from 3 to 6 tons of cherries harvested from 4-year-old trees. The average weight of the fruit ranges from 9 to 12 gm. and the average diameter of this particular selection is about 1.25 inches. (See figs. 1 and 2). In table 1 are recorded the yields of juice obtained by squeezing the fruits by hand through a piece of cloth, and also the vitamin C content per 100 ml. of juice, and the juice yielded per fruit.

Table 1 presents data on fruits of nine trees belonging to Selection B-17. The fruits were brought to the laboratory in polyethylene bags and placed in a freezer as soon as they were harvested. The analyses were performed within the following 48 hours.

Ten fruits were taken at random from each bag. Juice from 10 fruits was obtained as indicated above. The content of ascorbic and dehydroascorbic acids was determined by the method of Roe and Oesterlin (8) using 2,4-dinitrophenylhydrazine reagent. Ascorbic and dehydroascorbic acids are known to have equal vitamin C activity.

The B-17 selection, as can be judged from the data in table 1, is a high yielder of juice as well as of vitamin C in the juice per fruit. The yield of juice was as high as 73 percent of the weight of the fruit, while the vitamin C per 100 ml. of juice ranged from a minimum of 1,325 to a maximum of 2,250 mg.

It is also interesting to note the difference in vitamin C content of the cherries harvested in May and those harvested in June and August. This matter should be further investigated, as climatic conditions may be responsible for the observed variations.

According to the recommended dietary allowance of the National Research Council the vitamin C requirement for an average man is 75 mg.

TABLE 1.—*Average weight of 1 fruit, the yield of juice of 1 fruit, and the vitamin C in the juice of ripe cherries of West Indian cherry selection B-17*

Sample identification	Date harvested	Average weight of 1 fruit[1]	Yield of juice per fruit[2]	Vitamin C (ascorbic and dehydroascorbic acids) per 100 ml. of juice	Vitamin C (ascorbic and dehydroascorbic acids) in squeezed[2] juice, per fruit
		Grams	*Milliliters*	*Milligrams*	*Milligrams*
119 B-17	June 8, 1954	7.8	5.3	1,375	72.9
	Aug. 3, 1954	11.6	7.6	1,950	148.2
120 B-17	June 8, 1954	9.1	6.2	1,400	86.8
	Aug. 3, 1954	8.9	6.2	2,125	131.8
121 B-17	June 8, 1954	8.7	6.0	1,400	84.0
	Aug. 3, 1954	9.5	6.2	1,950	120.9
122 B-17	May 4, 1954	10.8	7.4	1,675	123.9
	Aug. 3, 1954	9.8	6.2	2,125	125.6
123 B-17	June 8, 1954	7.2	4.6	1,450	66.7
	Aug. 3, 1954	9.1	6.1	2,200	134.2
124 B-17	June 8, 1954	7.0	4.0	1,325	53.0
	Aug. 3, 1954	10.1	7.1	2,250	159.8
127 B-17	June 8, 1954	8.3	5.6	1,400	78.4
	Aug. 10, 1954	12.1	8.9	1,900	169.1
128 B-17	May 4, 1954	8.1	5.4	1,600	86.4
	Aug. 10, 1954	11.8	8.8	1,850	162.8
130 B-17	May 4, 1954	9.8	6.8	1,600	108.8
	Aug. 10, 1954	11.4	8.1	2,200	176.4

[1] 10 fruits averaged.

[2] Squeezed by hand through a piece of cloth.

per day. As can be seen in the last column of table 1, in the large majority of the cases a single cherry would provide this recommended dietary allowance.

ECONOMIC IMPORTANCE AND COMMERCIAL POSSIBILITIES OF WEST INDIAN CHERRY JUICE

Because of its perishable nature and acid taste we do not feel that the West Indian cherry will become of much value as a fresh fruit for the market. School children are fond of the brightly red-colored cherries and every school in the Island should have several trees planted in its yard. Several thousands have already been distributed by our Station.

It is as a source of natural vitamin C that the West Indian cherry has a promising economic future. As many pediatricians are of the opinion that baby foods should not be enriched with synthetic products, the use of small quantities of this juice will permit enrichment with natural vitamin C without resort to the synthetic vitamin.

SUMMARY

Six hundred and thirty-eight trees of "acerola", the West Indian cherry (*Malpighia punicifolia* L.) are under study at present.

The discovery made, in 1945, that the juice of this fruit had a high vitamin C content has given the "acerola" a potential economic importance since the juice can be extracted without loss of its nutritional value.

A selection of the fruit (B-17) at present under study has proved to be a high yielder of juice as well as of vitamin C. The fruit is also large.

The vitamin C content of the juice of 18 fruit samples from 9 trees of this selection ranged from 1,325 to 2,250 mgm. per 100 cc. of juice.

The vitamin C content of the juice of a single fruit of the analyzed samples ranged from 53 to 176 mg. Based on these values, the juice of one fruit of this selection will supply the minimum daily requirement of vitamin C for child or adult.

An apparent relationship between certain climatic factors and the vitamin C content of the fruit has been observed. Differences between values of the vitamin C content of the fruit harvested at different times during the year are so high that their cause should be investigated further.

RESUMEN

La acerola ha tomado importancia económica en Puerto Rico después del descubrimiento hecho en la Escuela de Medicina de la Universidad de Puerto Rico sobre el alto contenido de ácido ascórbico (vitamina C) que se encuentra en el jugo de esta fruta.

Los estudios hechos demuestran que la selección B-17 reune los requisitos adecuados en cuanto a tamaño y diámetro de la fruta y el contenido de vitamina C.

El contenido de vitamina C en el jugo de 18 muestras de frutas procedentes de 9 árboles de la Selección B-17 (dos de cada árbol) fluctuó entre 1325 y 2250 milígramos por cada 100 ml. de jugo.

El contenido de vitamina C en el jugo de cada fruta de las 18 muestras analizadas fluctuó entre 53 y 176 milígramos. A base de estos valores, el jugo de una acerola puede suplir, la mayoría de las veces, los requisitos diarios de vitamina C para un niño o adulto.

El alto contenido de vitamina C en el jugo de la acerola ofrece posibilidades comerciales en Puerto Rico.

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Notes on Puerto Rican Drosophilidae, Including Descriptions of Two New Species of Drosophila[1]

J. Ives Townsend[2] *and Marshall R. Wheeler*[3]

INTRODUCTION

Taxonomic interest in the Drosophilidae is great, primarily because of the value of the family for studies in genetics and evolution; thus it has become one of the very best known Dipteran families. Although no intensive effort has yet been made to obtain a large representative collection of Drosophilidae in Puerto Rico, Sturtevant (4)[4] has published a list of Puerto Rican species that he examined in several collections, and Wolcott (8) has published a list of species reported elsewhere in the literature.

REVISIONS WITHIN THE FAMILY AND COLLECTIONS IN PUERTO RICO

Several revisions have been made within the family (see, for example, 3, 7) since these Puerto Rican lists were published. Sturtevant included *Drosophila opaca* Williston and *D. caribbea* Sturtevant in his original list. However, he (5, p. 27) later transferred the former species to the genus Diathoneura. Duda (1, p. 223) pointed out that *D. caribbea* Sturtevant was a synonym of *D. ananassae* Doleschall. Sturtevant's list, with these changes to conform with current taxonomy, is indicated in column 1 of table 1. In column 2 of the same table a revision of Wolcott's list is indicated. On the authority given below the following names have been omitted from this list:

D. ampelophila Loew, according to Sturtevant (4, p. 105) a synonym of *D. melanogaster* Meigen

D. fusca Coquillett, according to Sturtevant (4, p. 106) a possible synonym of *D. lutzii* Sturtevant

[1] Collecting in Puerto Rico in 1952–53 was by the senior author, supported in part by a grant from the Penrose Fund of the American Philosophical Society. It is a pleasure to thank George N. Wolcott of the Agricultural Experiment Station of the University of Puerto Rico, Río Piedras, and Honorico Ciordia, formerly of that Station, for their generosity in lending their laboratory facilities and for their many other courtesies during the collecting, and to express appreciation to Frank H. Wadsworth of the U. S. Forest Service, Caribbean Division, Río Piedras, for his kindness in providing a guide and transportation for collecting in the Caribbean National Forest.

[2] Assistant Professor of Zoology, University of Tennessee, Knoxville, Tenn. This paper is Contribution No. 94 from the Department of Zoology and Entomology, University of Tennessee.

[3] Assistant Professor of Zoology, University of Texas, Austin, Tex.

[4] Numbers in parentheses refer to Literature Cited, p. 64.

TABLE 1.—*The Drosophilidae of Puerto Rico: Columns 1 and 2 are based on the publications of the indicated authors; columns 3, 4, and 5 report species collected in 1952 and 1953 in the localities indicated; in columns 3–5 the actual number of specimens collected is given when less than 6*

Species	Sturtevant (4)	Wolcott (8)	Río Piedras, September 1952	Río Piedras, June 1953	Caribbean National Forest, June 1953
Cladochaeta					
nebulosa Coquillett	x	x			
Diathoneura					
dubia? (Sturtevant)					x
opaca (Williston)			x	x	
species A					1♀
species B[1]					
Drosophila					
ananassae Doleschall	x	x	x	x	x
calloptera Schiner			1♂		
canapalpa? Patterson & Mainland				1♂	
cardini Sturtevant			x	x	x
dunni sp. nov.			x	x	x
equinoxialis Dobzhansky			x	x	
florae Sturtevant	x				
funebris (Fabricius)		x			
hydei Sturtevant	x				
lutzii Sturtevant	x	x			
melanica? Sturtevant		x			
melanogaster Meigen	x	x	x	x	x
mirim Dobzhansky & Pavan			x	x	x
nebulosa Sturtevant			x	x	x
paramediostriata sp. nov.			x	x	x
peninsularis Patterson & Wheeler			x	x	x
prognatha Sturtevant	x				
repleta Wollaston		x			
simulans Sturtevant	x				
similis Williston		x	?	? (1♂)	
sturtevanti Duda			x		3♀♀
tropicalis cubana Townsend			x	x	x
victoria Sturtevant			x		
willistoni Sturtevant			x	x	x
species A				x	
species B[2]				1♂	
Leucophenga					
frontalis (Williston)	x			3	
undulata (Hendel)				1	
varia (Walker)	x	x			
species A[3]				1	

TABLE 1.—*Continued*

Species	Sturtevant (4)	Wolcott (8)	Río Piedras, September 1952	Río Piedras, June 1953	Carribean National Forest, June 1953
Microdrosophila *quadrata* (Sturtevant)				x	x
Neotanygastrella *tricoloripes* Duda					x
Scaptomyza *vittata* (Coquillett)	?	x			

[1] Resembles somewhat *Diathoneura metallica* Sturtevant. A single female was taken in either Río Piedras or the Caribbean National Forest, Puerto Rico, in June 1953.

[2] Probably belongs to the annulimana group.

[3] Has dark wing pattern similar to, but more intense than, that of *Leucophenga maculosa*, but has quite different abdominal pattern, much narrower front, and palpi that are not noticeably enlarged.

D. punctulatus Loew, according to Sturtevant (4, p. 106) a synonym of *D. repleta* Wollaston

Stenomicra augustata Coquillett, according to Malloch (2, p. 23–24) best placed in the Asteiidae or Anthomyzidae; Sturtevant (6) relegates it to the Anthomyzidae.

Recently, incidental to the collecting of *Drosophila willistoni* in Puerto Rico, a number of Drosophilidae not previously reported from this Island have been obtained. Collections were made on the grounds of the Agricultural Experiment Station of the University of Puerto Rico, Río Piedras, September 10–12, 1952, and June 9–12, 1953, and also in the Caribbean National Forest, June 10, 1953. Windfallen, fermenting fruits—principally *Artocarpus communis* and *Annona reticulata* in 1952, and *A. communis* and *Mangifera indica* in 1953—were the most effective bait. Yeasted banana pulp was used to supplement these fruits. The Drosophilidae taken in these collections are indicated in columns 3, 4, and 5 of table 1. These include several previously undescribed species, of which two species of Drosophila are described below.

Although ecological conditions in southern Florida and in Puerto Rico are rather different, they are still similar enough to make interesting a comparison of species of Drosophilidae known from these two regions. For this purpose all Drosophilidae that have been taken by collectors from the University of Texas laboratories or by the senior author in Florida south

of the 29th parallel are listed in the following tabulation:

The Drosophilidae of peninsular Florida south of the 29th Parallel, based on collections made by collectors from the University of Texas and by the senior author:

Drosophila

acutilabella Stalker[1]
affinis Sturtevant
americana texana Patterson, Stone, & Griffen
ananassae Doleschall
busckii Coquillett
cardini Sturtevant
deflecta Malloch & McAtee
duncani Sturtevant
guttifera Walker
hydei Sturtevant
immigrans Sturtevant
macrospina Stalker & Spencer
melanica Sturtevant
melanissima Sturtevant
melanogaster Meigen
micromelanica Patterson
mirim Dobzhansky & Pavan
mulleri Sturtevant
nebulosa Sturtevant
nigromelanica Patterson & Wheeler
peninsularis Patterson & Wheeler
putrida Sturtevant
repleta Wollaston
robusta Sturtevant
simulans Sturtevant
transversa Fallen
tripunctata Loew
virilis Sturtevant
willistoni Sturtevant

Chymomyza

procnemis (Williston)

Diathoneura

opaca (Williston)

Gitona

americana Patterson
bivisualis Patterson

Leucophenga

maculosa (Coquillett)
varia (Walker)

Microdrosophila

quadrata (Sturtevant)

Mycodrosophila

dimidiata (Loew)

Scaptomyza

adusta (Loew)
vittata (Coquillett)

[1] Kindly identified by Harrison D. Stalker.

The 26 species of Drosophila and 12 species of non-Drosophila Drosophilidae now reported from Puerto Rico compare favorably with the 29 and the 10 species in the respective classes reported from southern Florida. Nevertheless the Puerto Rican list is by no means exhaustive. One indication of this is the fact that at least two cosmopolitan species, *Drosophila busckii* Coquillett and *D. immigrans* Sturtevant, very likely present in the Island are yet to be reported from there. It appears that further collecting in Puerto Rico will be rewarding to the taxonomist and illuminating to the evolutionist who, since Darwin, has increasingly appreciated the importance of insular species.

DESCRIPTIONS OF SPECIES

Types of the following new species have been deposited in the collections of the Department of Zoology of the University of Texas; some paratypes have been deposited in the collection of the Department of Zoology and Entomology of the University of Tennessee.

Drosophila dunni, SPECIES NOVA

External characters of imagines

♂. Arista with about 8–10 branches, 9 being the usual number. Antennae tan, third joint somewhat darker. Front tan, dull and velvety except ocellar triangle and area of orbital bristles. Middle orbital about ⅓ other 2. Second oral bristle about as long as first. Carina broad and flat; face yellowish tan. Cheeks pale yellow, their greatest width about ⅕ greatest diameter of eyes. Eyes bright red, clothed with short black pile.

Acrostichals in 6 rows; no prescutellars. Anterior scutellars convergent. Mesonotum, scutellum, and pleurae shining brownish tan. Sterno-index about 0.5. Legs yellow; fore tarsi with many short recurved hairs, their length about equal to the diameter of the tarsal segments. Apical bristles on first and second tibiae, preapicals on all 3.

Abdomen shining yellow, each segment with a medianly interrupted, narrow apical band which narrows and becomes fainter at the angle of the tergite; some individuals with bands very faint and scarcely discernible.

Wings clear. Costal index about 3.5; fourth-vein index about 1.9; 5x index about 1.8; 4c index about 0.8. One prominent bristle at apex of first costal section. Third costal section with heavy bristles on basal ⅓.

Length body 2.3 mm. (in live specimen); wings 1.9 mm.

♀. Fore tarsi with few, or no, short recurved hairs. Length body 2.7 mm.; wings 2.3 mm.

Internal characters of imagines

Testes with about 4 pale yellow outer coils and 3½ whitish inner coils or gyres.

Spermathecae medium brown in color and chitinized. Ventral receptacle with about 15 coils in long spiral.

Single anterior Malpighian tube, branched at distal end; 2 posterior tubes with distal ends opposed without formation of a continuous lumen.

Other characteristics, relationship, and distribution

EGGS.—4 filaments, tapering toward distal ends. Egg length about 0.52 mm.

PUPARIA.—Amber. Each anterior spiracle with about 11 branches. Hor
index about 5.0.

CHROMOSOMES.—Metaphase plate with a pair of short rods, a pair
long rods, and 2 pairs of U's.

RELATIONSHIP.—Belongs to the cardini group of the subgenus Drosophil

DISTRIBUTION.—Puerto Rico: Río Piedras and Caribbean Nation
Forest.

HOLOTYPE MALE.—Holotype and paratypes descendants of a sing
female collected at Río Piedras in September 1952.

N. b.: This species is named in honor of L. C. Dunn of Columbia Un
versity.

Drosophila paramediostriata, SPECIES NOVA

External characters of imagines

♂. Arista with about 10–12 branches. Antennae tan, third joint som
what darker. Front tannish brown. Anterior orbital about ¾ posterio
middle orbital little larger than surrounding hairs. Second oral brist
about as long as first. Carina wider below, flat, not sulcate. Palpi pale yello
with several prominent bristles. Face tannish yellow. Cheeks pale yello
their greatest width about ¼ greatest diameter of eyes. Eyes red, wit
light-colored pile.

Acrostichals in 6 rows; no prescutellars. Anterior scutellars divergen
Mesonotum and scutellum tannish brown without markings; pleura
lighter. Sterno-index about 0.6. Legs pale yellowish tan. Apical bristles o
first and second tibiae; preapicals on all 3. Front femora with an imm
granslike row of short black spines.

Abdomen dark yellow, each segment with a broad apical brown ban
each band usually extending to lateral margin except on basal segmen
apical bands on tergites 1–3 thinner in middle; apical bands on tergite
4–6 each with median projection, sometimes reaching anterior margin o
tergites 5 and 6, but not on tergite 4; bands larger and darker in posteri
segments.

Wings with posterior crossveins slightly clouded, remainder clear. Cost
index about 3.8; fourth-vein index about 1.6; 5x index about 1.5; 4c inde
about 0.7. Apex of first costal section with two well-developed bristle
Third costal section with heavy bristles on basal ½.

Length body 2.2 mm. (in live specimen); wings 2.2 mm.

♀. Length body 2.7 mm; wings 2.5 mm.

Internal characters of imagines

Testes pale yellow with about 3 outer and 3 inner coils or gyres. Ejacu
latory sac with 2 long posterior diverticula.

Spermathecae spherical, lightly chitinized. Ventral receptacle with about 26 irregular coils.

Other characteristics, relationship, and distribution

EGGS.—4 slender filaments; egg length about 0.44 mm.

PUPARIA.—Reddish amber. Each spiracle with about 20 branches. Horn index about 3.0.

CHROMOSOMES.—Metaphase plate with 5 pairs of rods and 1 pair of dots; 1 pair of rods about twice as long as others.

RELATIONSHIP.—Belongs to the tripunctata group of the subgenus Drosophila. It is very similar to *D. mediostriata* Duda, but that species has a median spot without a band on the sixth tergite; there are also some small differences in the male genitalia.

DISTRIBUTION.—Collected in Puerto Rico: Río Piedras and Caribbean National Forest.

HOLOTYPE MALE.—Holotype and paratypes descendants of females collected at Río Piedras in September 1953.

SUMMARY

When necessary allowances are made for conformity with current taxonomy of the Drosophilidae, it is seen that 15 species, of which 11 are Drosophila and 4 non-Drosophila Drosophilidae, have previously been reported from Puerto Rico. Recent, but not extensive, collecting in this Island has resulted in capture of 27 species of Drosophilidae. Eight species of non-Drosophila Drosophilidae and 15 species of Drosophila in the recent collections have not previously been reported from Puerto Rico. Among these unreported forms are two new species of Drosophila that are described herein.

The number of species of Drosophilidae now reported from Puerto Rico compares favorably with that reported from peninsular Florida south of the 29th parallel.

RESUMEN

Cuando se hacen las necesarias concesiones a la taxonomía corriente de las Drosophilidae, se ve que 15 especies, de las cuales 11 son Drosophila y 4 no Drosophila Drosophilidae, se han informado previamente de Puerto Rico. Recientemente, aunque no en forma extensiva, el esfuerzo hecho por colector este género de insectos en la Isla ha redundado en la captura de 27 especies de Drosophilidae. Ocho especies no Drosophila Drosophilidae y 15 especies Drosophila incluídas en las recientes colecciones no se habían informado previamente de Puerto Rico. Entre estas formas sin informar hay 2 nuevas especies de Drosophila las cuales se informan en este trabajo.

El número de especies de Drosophilidae, hasta ahora informado de Puerto Rico, compara favorablemente con el de la peninsula de Florida, al sur del paralelo 29.

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Organic-Matter Activity of Some Typical Soils of Puerto Rico

Fernando Abruña-Rodríguez and José Vicente-Chandler[1]

INTRODUCTION

Although considerable such information is available from Temperate regions, relatively little is known about the activity of organic matter in Tropical soils.

The objectives of the study herein reported were (1) to evaluate the exchange capacity of the organic matter in samples of the most important soils of Puerto Rico by using three different methods, and (2) to determine the exchange capacity of portions of the organic matter variously resistant to oxidation.

MATERIALS AND METHODS

Surface samples representing the Catalina, Cialitos, Alonso, Los Guineos, Múcara, Jayuya, Utuado, Río Piedras, Coto, Matanzas, and Nipe soil series were used in this study. Roberts (13)[2] has described these soils in detail. All are kaolinitic with the exception of Múcara the clay minerals of which are mainly of the expanding lattice type (1).

After the soil samples were air-dried, organic matter was determined by the wet-combustion method. A previously determined (14) correction factor of 1.2 was used in the calculation of total carbon from oxidized carbon. Total nitrogen was determined by the Kjeldahl method. PH values were ascertained with a glass electrode potentiometer. Cation-exchange capacities were determined by the ammonium acetate method. The pipette method was used in performing the mechanical analyses.

The exchange capacity of the organic matter was evaluated by three different methods as follows:

THE "DIFFERENCE" METHOD

The organic-matter content and the cation-exchange capacity of the soil samples were determined before and after destruction of most of the organic matter with hydrogen peroxide. The reduction in exchange capacity was assumed to be due to the loss of organic matter. From these data the exchange capacity of the organic matter was calculated.

[1] Soil Scientist and Superintendent of the Cooperative ARS Research Project, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[2] Numbers in parentheses refer to Literature Cited, pp. 75–6.

TABLE 1.—*The cation-exchange capacity of the organic matter as determined by the "difference method," and related data for samples of 11 Puerto Rican soils*

Soil sample	pH	C:N of untreated soil	Clay	Silt	Organic matter—		Cation-exchange capacity—		Apparent exchange capacity of organic matter	Contribution of organic matter to exchange capacity of soil
					In untreated soil	In soil after H_2O_2 treatment	Of untreated soil	Of soil after H_2O_2 treatment		
		Ratio	*Percent*	*Percent*	*Percent*	*Percent*	*M.e./100 gm.*	*M.e./100 gm.*	*M.e./100 gm.*	*Percentage of total*
Cialitos:										
3	5.1	10.3	31.5	37.6	2.62	0.69	14.89	11.89	155	20.1
83	5.3	10.6	27.9	48.1	2.75	.63	14.65	12.19	116	16.8
85	4.9	9.0	18.8	52.3	2.87	.56	16.22	13.87	102	14.5
95	5.0	10.0	36.7	52.6	4.30	.66	12.72	9.61	85	24.4
98	4.7	7.6	30.0	46.2	1.31	.50	16.61	15.86	93	4.5
Average	5.0	9.5	33.0	43.36	2.77	.61	15.02	12.68	110	16.06
Catalina:										
8	5.0	8.7	51.4	35.1	3.46	0.63	17.81	12.58	185	29.4
61	5.2	10.5	48.8	40.0	4.72	.63	19.23	15.56	90	19.1
80	4.9	13.0	24.1	45.9	3.82	.50	20.26	18.13	64	10.5
81	4.7	9.6	23.4	32.7	3.58	.63	16.76	12.39	148	26.1
82	5.2	9.8	27.6	42.4	4.42	.38	19.67	15.36	107	21.9
91	4.8	9.4	44.2	39.5	2.75	.38	18.68	16.55	90	11.4
92	5.9	9.0	55.7	32.8	3.22	.24	22.68	19.13	119	15.7
93	4.9	9.2	45.7	38.7	2.99	.50	17.75	16.65	44	6.2
Average	5.1	9.9	40.11	38.37	3.62	.49	19.16	15.79	106	17.5
Los Guineos:										
4	4.3	11.3	42.7	46.2	6.40	0.50	17.85	9.91	135	44.5

Los Guineos:										
4	4.3	11.3	42.7	46.2	6.40	0.50	17.85	9.91	135	44.5
22	4.6	10.6	55.5	34.2	5.89	.50	16.66	12.49	77	25.0
67	4.8	8.8	—	—	5.81	.75	22.28	15.56	133	30.2
68	4.2	19.1	58.1	31.5	7.56	.63	21.05	9.22	171	56.2
75	4.0	9.6	35.2	53.5	4.48	.38	14.40	6.94	182	51.8
89	5.3	9.6	23.4	48.6	3.46	.82	14.30	11.89	91	16.9
90	5.2	7.1	27.1	53.1	2.39	.69	23.37	19.42	232	16.9
Average	4.6	10.9	40.3	44.4	5.14	.61	18.60	12.20	146	34.5
Alonso:										
12	5.2	10.3	48.7	36.4	4.48	0.47	20.76	17.44	83	16.0
21	4.5	12.3	53.1	36.2	6.27	.25	22.18	16.45	95	25.8
Average	4.8	11.3	50.9	36.3	5.37	.36	21.47	16.95	89	20.9
Mucara:										
9	5.8	10.1	22.5	42.2	3.26	0.50	25.83	20.61	189	20.2
87	5.7	8.3	11.6	28.3	1.91	.38	24.74	22.79	127	7.9
Average	5.8	9.2	17.0	35.2	2.58	.44	25.29	21.70	158	14.0
Rio Piedras 6	4.9	10.2	—	—	3.90	0.38	16.96	11.40	158	32.8
Nipe 29	5.7	15.5	70.3	19.3	5.64	.63	11.21	6.84	87	39.0
Coto 30	7.7	13.3	49.9	10.4	2.87	.63	12.02	6.94	227	42.3
Matanzas 31	7.6	9.2	78.0	3.2	5.01	1.19	15.38	9.71	148	36.9
Jayuya 32	5.7	11.6	34.9	22.5	6.78	.75	16.07	11.30	79	29.7
Utuado 69	5.1	10.6	13.40	24.0	4.48	.75	15.73	11.16	124	29.4

TITRATION OF EXTRACTED ORGANIC MATTER

The organic matter of selected samples was extracted following the procedure used by Marshall and Patnaik (6), with only minor modifications. The procedure used was as follows: 200 gm. of air-dry soil were shaken with 2 l. of 0.02 N HCl. After standing overnight, the supernatant liquid was siphoned off and the soil washed with distilled water until free of chlorides. The residue was then shaken with 2 l. of 0.5 N Na_2CO_3 solution and left overnight. The dissolved material was siphoned off and transferred to a jar with 1 l. of 5-percent NaCl solution to flocculate any suspended inorganic material. After standing 8 hours the dark-colored solution was siphoned off, filtered, and then slowly acidified with dilute HCl. The organic matter precipitated by the acid was then centrifuged and freed from the supernatant liquid. It was again dissolved in Na_2CO_3 and precipitated as before. Finally, the flocculent precipitate was washed with distilled water until free of soluble salts. An organic-matter suspension was obtained by dispersing the material in distilled water.

The exchange capacity of the extracted organic matter was determined by titration in aqueous solution with calcium hydroxide. Nine days were allowed for the reaction to be completed. As the organic material was easily dispersed in water, concentration was determined by evaporating a known volume of liquid at 105° C. and weighing the residue.

CORRELATION BETWEEN EXCHANGE CAPACITY AND ORGANIC-MATTER CONTENT

The cation-exchange capacity and organic-matter content of samples from two similar soils (Coto and Catalina) were determined. These values were also determined for samples taken at varying depths in a Catalina soil. The exchange capacity of the organic matter was estimated from the relationship existing between the organic-matter content and the total exchange capacity of the soil samples.

The exchange capacity of the organic matter which could be separated from two samples of Catalina soil by flotation was determined. This fraction of the organic matter was obtained by placing the oven-dry soil in a beaker of water and removing all the organic matter which floated on the surface.

Subsamples from these two soil samples were treated with different concentrations of hydrogen peroxide over different time intervals. It was assumed that with this treatment portions of the organic matter with varying resistance to oxidation were destroyed. Organic-matter and exchange-capacity determinations were made on the samples before and after treatment with hydrogen peroxide. From these data the exchange capacity of the various portions of the organic matter was calculated.

RESULTS

Analytical data for the soil samples studied are shown in table 1. The range of organic matter-values and C:N ratios was about normal for these soils (14). All the samples were acid with the exception of those from the Coto and Matanzas soil series. These soils were derived from limestone and,

TABLE 2.—*Analysis of the organic matter extracted from samples of 4 typical soils of Puerto Rico*

Soil samples		Cation-exchange capacity	Ash	Nitrogen	Carbon	C:N Ratio
Soil	Number					
		M.e./100 gm.	*Percent*	*Percent*	*Percent*	
Cialitos	3	180	1.19	4.02	52.24	13.0
Catalina	8	220	1.53	5.01	50.85	10.1
Do.	61	200	1.62	5.17	50.40	9.7
Los Guineos	4	238	3.64	4.80	58.71	12.2
Do.	22	220	3.22	5.41	56.20	10.4
Alonso	12	260	2.32	4.05	50.06	12.4
Do.	21	290	2.44	4.32	50.61	11.7

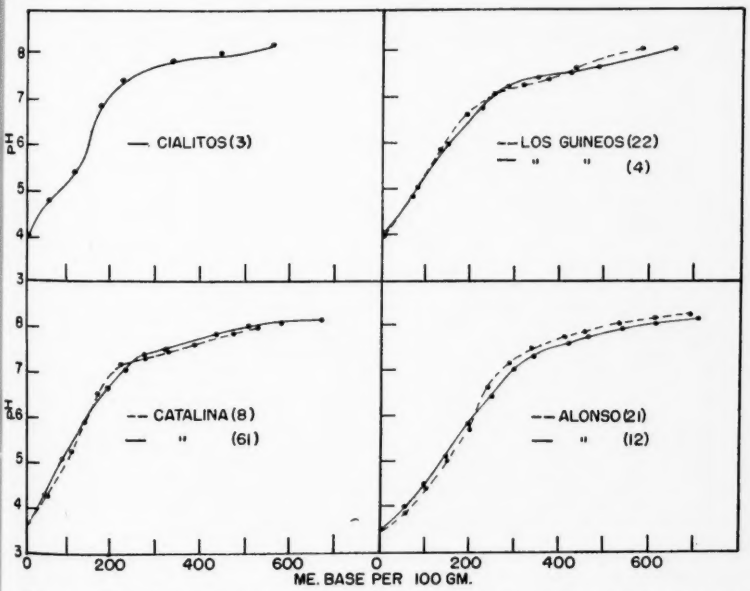

FIG. 1.—Titration curves of organic matter extracted from samples of 4 typical soils of Puerto Rico.

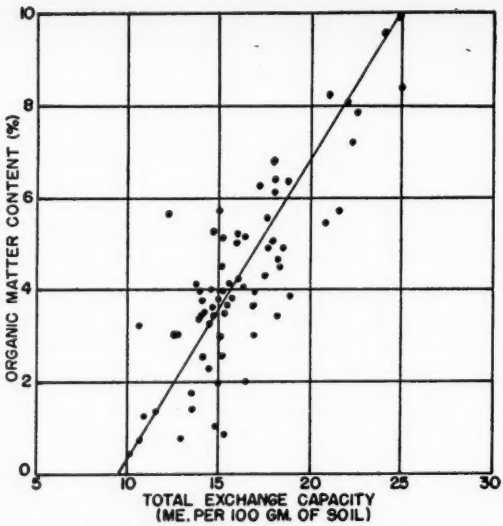

FIG. 2.—The activity of soil organic matter as indicated by the relationship between exchange capacity and organic-matter content of 73 samples of 2 kaolinitic clay soils—Catalina and Coto. Each 100 gm. of organic matter appears to have an average exchange capacity of about 150 m.e.

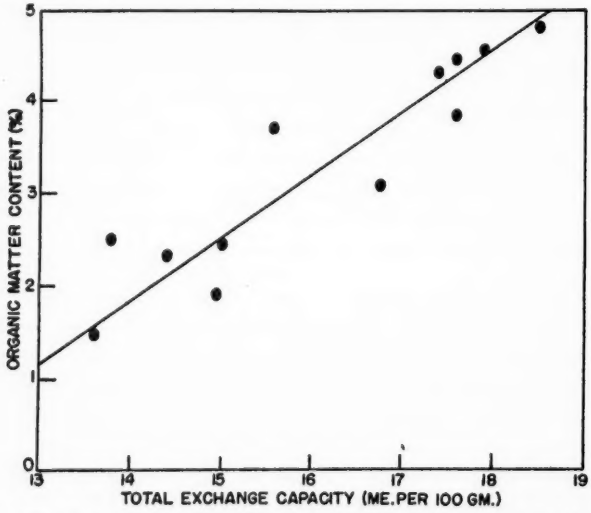

FIG. 3.—The activity of soil organic matter as indicated by the relationship between exchange capacity and organic-matter content of samples of a Catalina clay soil taken at different depths. Each 100 gm. of organic matter appears to have an average exchange capacity of about 138 m.e.

though normally acid, there are areas where the soils are neutral to alkaline due to the influence of marley exposures of the parent material.

The results of the study to determine organic-matter activity by the difference method are summarized in table 1. The organic matter accounted for from 4.5 to 56.2 percent of the exchange capacity of these soils (average = 24.7 percent). The apparent cation-exchange capacity of the organic matter varied rather widely, from 44 to 232 (average = about 125) m.e./100 gm. of organic matter. Most of the values, however, were within the range of from 80 to 160 m.e./100 gm. of organic matter.

The cation-exchange-capacity values of the extracted organic matter are given in table 2. The values obtained by this method were in all cases

TABLE 3.—*The apparent exchange capacity of organic-matter fractions variously resistant to oxidation with hydrogen peroxide*[1]

Sample and treatment	Nitrogen	C:N ratio	Organic matter	Cation-exchange capacity of soil	Apparent-cation exchange capacity of organic matter
	Percent		*Percent*	*M.e./100 gm.*	*M.e./100 gm.*
Sample 254:					
None	0.34	11.6	6.79	18.03	—
Minus organic matter removed by flotation	.28	11.6	5.58	13.09	408
15-percent H_2O_2 for 1 hr.	.17	11.0	3.23	8.15	210
15-percent H_2O_2 for 2 hr.	.13	11.0	2.48	6.87	157
15-percent H_2O_2 for 4 hr.	.11	11.1	2.11	6.87	0
30-percent H_2O_2 for 4 hr.	.06	12.0	1.24	6.00	100
30-percent H_2O_2 for 6 hr.	.06	9.5	.99	6.52	0
30-percent H_2O_2 overnight	.05	7.2	.62	6.51	0
Average for all organic matter destroyed					187
Sample 256:					
None	0.38	12.5	8.17	21.03	—
Minus organic matter removed by flotation	.33	12.0	6.83	15.02	448
15-percent H_2O_2 for 1 hr.	.26	11.1	4.96	12.44	138
15-percent H_2O_2 for 2 hr.	.23	10.9	4.34	10.94	242
15-percent H_2O_2 for 4 hr.	.17	11.0	3.23	9.23	154
30-percent H_2O_2 for 4 hr.	.14	10.3	2.48	8.14	145
30-percent H_2O_2 for 6 hr.	.05	10.1	.87	8.80	0
30-percent H_2O_2 overnight	.05	7.2	.62	8.74	0
Average for all organic matter destroyed					162

[1] Both samples are of Catalina soil with a clay content (kaolinitic) of about 50 percent and a pH of 4.6.

much higher than those obtained by the difference method. They ranged from 180 to 290 (average = 230) m.e./100 gm. of organic matter.

The titration curves for the extracted organic matter are shown in figure 1. All the curves show a high buffer capacity above pH 7. The curves for all samples are similar, the main difference lying in their neutralization capacities.

Figure 2 shows the relationship between the exchange capacity and the organic-matter content of 73 samples of Coto and Catalina soils taken from several widely varying locations. These data indicate that the exchange capacity of the soil organic matter averaged about 150 m.e./100 gm. of organic matter.

Figure 3 shows the relationship between the exchange capacity and the organic-matter content of samples of Catalina soil taken at different depths at the same location. These data indicate that the exchange capacity of the organic matter averaged about 138 m.e./100 gm. of organic matter.

The results of the study to determine the exchange capacity of various portions of the organic matter of two soil samples are given in table 3. With both samples the organic matter removed by flotation had an extremely high exchange capacity (over 400 m.e./100 gm. of organic matter). The final fractions of organic matter, i.e. those which were most resistant to oxidation, had no apparent exchange capacity. Within these extremes the data seem to indicate that, in general, the portions of organic matter which were most readily oxidized were the most active.

DISCUSSION OF RESULTS

Most of the soil samples studied had C:N ratios of about 10:1, indicating that the organic matter was well decomposed. There was no apparent relationship between soil pH and the exchange capacity of the organic matter.

The variations in the exchange capacity of the organic matter of the various samples as determined by the difference method were generally in line with the findings of Olson and Bray (11) and of Mitchell (8) who found values ranging from 34 to 283 and from 70 to 200 m.e./100 gm. of organic matter, respectively, with soils of the United States. Ayers (2) reported an average exchange capacity of 200 m.e./100 gm. for the organic fraction of latosols from Hawaii, and Craig (4) reported even higher values for a group of soils from Mauritius.

The much higher exchange values obtained by titrating the extracted organic matter are in line with the results of almost all researches on this subject. It may be that only the more active portions of the organic matter were extracted. The similarity between the C:N ratios of the extracted organic matter and those of the normal soil, however, would tend to indicate that a representative portion of the organic matter was extracted. As

noted by McGeorge (7) the exchange capacity of extracted organic matter depends largely upon the method of extraction used, so any results obtained with this procedure are of doubtful validity.

The ash content of the organic matter has little meaning since there is no way of determinign what part came from inorganic colloids not properly separated from the organic matter, or from inorganic-organic complexes which actually formed part of the organic matter.

The high buffer capacity of the extracted organic matter above pH 7 is in line with the findings of Baver (3). The formation of insoluble calcium humates may have something to do with this characteristic as pointed out by Puri (12).

Despite wide variability, the estimated exchange values obtained from the relationship between organic-matter content and the total cation-exchange capacity of the soil samples, are generally of the same order of magnitude as the values obtained by the difference method. The former method, though obviously impractical, would appear to give the most reliable information since the analyses are performed on untreated soil samples. The general agreement found between both methods would seem to lend validity to the difference method for routine laboratory determinations of the exchange capacity of the organic fraction of soils.

The high exchange capacity of the organic matter removed by flotation is of practical importance. Obviously, this material is easily removed by water and even a small run-off could carry away important quantities of this organic fraction, thus considerably reducing the exchange capacity of the soil.

That the more readily oxidizable portion of the organic matter appears to be the most active is also of practical importance. When the soil is exposed, this part of the organic matter is probably oxidized at a relatively high rate, the less active portion remaining in the soil. Adequate soil cover thus appears to be essential to the conservation of this part of the organic matter in view of the very high temperatures attained by exposed surface soils (16).

The data presented in table 3 indicate that the portion of organic matter most resistant to oxidation has no apparent exchange capacity. This is in agreement with the findings of Olson and Bray (11), except that a higher proportion of the organic matter of Puerto Rican soils is apparently in this category. The exchange capacity of the soil in some cases appears to increase following destruction of this portion of the organic matter. These findings suggest a blocking of exchange positions on the clay colloids by the organic matter. The difficulty of destroying this portion of the organic matter likewise points to a close tie-in between clay colloids and soil organic matter.

This fraction of the organic matter is relatively high in nitrogen as indicated by narrow C:N ratios. This suggests that clay-protein complexes of the type described by Norman (10) may be active in binding the clay and organic fractions. Ensminger and Gieseking (5) found that proteins can be strongly absorbed by bentonite through the basic groups acting as exchangeable bases. It is of interest to note that Myers (9) found that the association of clay and organic matter is most likely to occur with large exposed surfaces and under acid conditions such as those occurring with most of the soils studied. The large surface areas of the clay fraction of these soils are indicated by their high wilting points (1) and by their ability to orient or "pack" water molecules (15).

The strong resistance to oxidation of a considerable portion of the organic matter helps to explain the relatively high organic-matter contents of even continuously clean-cultivated soils in Puerto Rico.

SUMMARY

The exchange capacity of the organic matter in typical soils of Puerto Rico was evaluated from: (1) The variation in the exchange capacity of soil samples following destruction of the organic matter, (2) titration curves of extracted organic matter, (3) and the correlations between exchange capacity and organic-matter content of soil samples. The first method was the most practical and gave fairly accurate results. The second method gave results which were in all cases too high. The third method, though probably the most accurate, is impractical. Results obtained with the first and third methods were similar.

The exchange capacity of the organic matter varied rather widely, but was generally between 100 and 150 m.e. per 100 gm. On the average it accounted for about 25 percent of the total exchange capacity of the soils studied.

The organic matter removed by flotation had the highest exchange capacity and the more readily oxidizable portions generally appeared to be the most active. This suggests the importance of conserving the more readily lost portions of the soil organic matter.

A considerable portion of the soil organic matter was extremely resistant to oxidation, had a narrow C:N ratio, and apparently little exchange capacity. This suggests a close association between the organic matter and the inorganic soil colloids. The marked resistance to oxidation of a considerable portion of the organic matter may partly explain the high contents found even in continuously cultivated soils in Puerto Rico.

RESUMEN

Se determinó la capacidad de cambio de la materia orgánica de un grupo de suelos típicos de Puerto Rico usando tres métodos de análisis: (1) Varia-

ción en la capacidad de cambio de las muestras de suelo al destruirse la materia orgánica. (2) Titulación potenciométrica de los coloides orgánicos extraídos del suelo con carbonato de sodio. (3) Correlación entre el contenido de materia orgánica y la capacidad de cambio de un grupo considerable de muestras de suelos similares. El primer método resultó ser el más práctico y fácil de llevar a cabo. Dió resultados muy parecidos a los obtenidos usando el método de correlación que es probablemente el más preciso. Este último método es, sinembargo, poco práctico. El segundo método dió los resultados más altos.

La capacidad de cambio de la materia orgánica en las distintas muestras varió considerablemente, estando la mayoría entre 100 y 150 m.e./100 gramos. Los resultados demostraron que la materia orgánica contribuye alrededor de un 25 por ciento de la capacidad de cambio total en los suelos estudiados.

Se demostró que la fracción de la materia orgánica que se puede separar por medio de la flotación en agua, tiene una capacidad de cambio mayor que ninguna otra porción. Igualmente, la fracción mas propensa a la oxidación mostró una capacidad de cambio mayor que las fracciones más resistentes.

Aparentemente, una parte considerable de la materia orgánica de los suelos de Puerto Rico está combinada íntimamente con la porción mineral y contribuye muy poco a la capacidad de cambio total del suelo. Esta fracción orgánica es muy resistente a la oxidación y esto explica el alto contenido de materia orgánica aún en suelos cultivados contínua e intensivamente.

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Influence of Fertilizers on the Yield of the Plamar Variety of Tomatoes on a Coto Clay

Pablo Landrau, Jr., and George Samuels[1]

INTRODUCTION

Most of the tomatoes and tomato products consumed in Puerto Rico are imported. In the fiscal year 1950–51, $2,400,000 was spent on imported tomato pastes and purees (1),[2] whereas in the same period a farm income of only $893,000 was realized by the Puerto Rican farmers from growing tomatoes. The area in tomatoes in Puerto Rico for 1950–51 was 2,694 acres with an average yield of 64.3 hundredweights of tomatoes per acre.

The expansion of tomato production in Puerto Rico has been recommended primarily to supply our own needs. It has been claimed that our farmers must improve their cultivation practices to do this profitably. These practices include the use of better lands, larger plantings, irrigation, improved varieties, application of adequate fertilizers, and control of insects and diseases by spraying. (1).

It is the purpose of this article to report how fertilizers influence the yields of the Plamar variety of tomatoes on Coto clay, a soil much used for tomato production.

PROCEDURE

To study the influence of fertilizers on the yield of tomatoes, a field experiment was planted August 15, 1952, on a Coto clay at the Isabela Substation. The Isabela area is located on the northwestern corner of Puerto Rico and has an average altitude of about 300 feet above sea level. The land is devoted mainly to sugarcane. Other crops such as pineapple, tomatoes, peppers, tobacco, cotton, and corn do well, if irrigated. The land is owned mainly by farmers with small acreages. The average yearly rainfall is 66 inches, precipitation being considerably below average during the winter months. Because of a dry spell, the 15.57 inches of rain which fell during the 3-month experimental period was augmented with four irrigations.

Coto clay is a permeable yellowish-colored clay derived from Tertiary limestone. Its pH ranges normally from 5.0 to 6.5. A description of a soil

[1] Assistant Agronomist and Agronomist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R. The authors wish to thank Rafael García, former Research Assistant in Agronomy at the Isabela Substation and other members of the Substation for their help in the fieldwork.

[2] Numbers in parentheses refer to Literature Cited, pp. 82–3.

profile of Coto clay can be found in a previous publication by the authors (2).

The experiment here reported included 16 fertilizer treatments replicated 6 times in a triple-lattice field design. The size of the plots was 10 by 12 feet, or about one three-hundred-and-sixty-third of an acre in area. A total of 15 plants per plot were planted in rows 4 feet apart with a distance of 2 feet between plants, and using the hill system of planting. The tomato variety used was the Plamar which is blight-resistant and outyields the imported varieties during the summer months.

The fertilizer treatments consisted of applying various quantities of the major fertilizer elements and of two minor elements. Filter-press cake, a byproduct of the sugarcane mills, was also tried as a soil ameliorator, both by itself and in combination with chemical fertilizers. All fertilizer, except for the filter-press cake, was applied after the plants were set out in the field. Filter-press cake was placed in the hole before planting, and for one split-fertilizer application, followed by another application 6 weeks after the other plants were fertilized.

The experiment was planted on August 25, 1952, and was harvested on October 15, 1952, and on November 17, 1952. At time of harvest, the pickings were divided into commercial marketable size (above 0.2 pound) and culls (less than 0.2 pound) and unmarketable. Besides weight of tomatoes, counts of tomatoes per plot were made to determine the mean weight of the commercial fruit.

RESULTS

NITROGEN

The yield of tomatoes was definitely increased by the use of nitrogen fertilizers. The use of 100 pounds of N per acre gave an increase in marketable tomatoes of 41.9 hundredweights, or 97 percent over the treatment where no nitrogen was applied (table 1, treatment 2 minus treatment 1). The use of 100 pounds of N per acre also reduced the percentage of culls from 46 to 38 and increased the mean weight of the commercial fruit from 2.29 to 2.45 ounces.

When 200 pounds of N per acre was applied, there was a slight decrease of about 7 hundredweights in yield over the 100-pound N-per-acre treatment. The 200-pound N-per-acre treatment also raised the percentage of culls to 44 as compared with 38 with the 100-pound N-per-acre treatment, and slightly reduced the mean fruit weight. For the conditions of this experiment, when sufficient P_2O_5 and K_2O are present, 100 pounds of N per acre appeared to be sufficient to produce optimum yields of Plamar tomatoes.

TABLE 1.—*Influence of various fertilizer treatments on the yield of Plamar tomatoes*

Treatment No.	Treatment per acre of—			Yield of tomatoes per acre			Culls	Mean weight of commercial fruit
	N	P_2O_5	K_2O	Commercial size	Culls	Total production		
	Pounds	*Pounds*	*Pounds*	*Cwt.*	*Cwt.*	*Cwt.*	*Percent*	*Ounces*
1	0	200	200	43.2	37.3	80.5	46	2.29
2	100	200	200	85.1	51.3	136.4	38	2.45
3	200	0	200	47.5	37.2	84.7	44	2.36
4	200	100	200	57.1	48.1	105.2	46	2.33
5	200	200	0	86.3	59.1	145.4	41	2.25
6	200	200	100	76.9	51.4	128.3	40	2.44
7	200	200	200	78.4	58.3	136.7	43	2.34
8	0	0	0	19.1	18.4	37.5	49	2.41
9[1]	0	0	0	38.5	30.1	68.6	44	2.23
10[2]	0	0	0	41.1	42.9	84.0	51	2.20
11[1]	100	200	200	86.6	48.4	135.0	36	2.49
12[2]	100	200	200	106.3	52.6	158.9	33	2.48
13[3]	200	200	200	63.0	43.4	106.4	41	2.29
14[4]	200	200	200	57.2	43.3	100.5	43	2.30
15[5]	200	200	200	92.9	50.0	142.9	35	2.53
Least significant difference needed between treatment means:								
5-percent level:				21.2	12.6	30.9		0.22
1-percent level:				28.2	16.7	41.1		.29

[1] Plus 10 tons filter-press cake.
[2] Plus 20 tons filter-press cake.
[3] Plus 50 pounds borax.
[4] Plus 100 pounds MgO.
[5] Fertilizer applied in 2 applications, one-half when plants were set in field, one-half 6 weeks after this.

PHOSPHORUS

The use of phosphate fertilizers increased yields of tomatoes very significantly. The use of 100 pounds of P_2O_5 per acre gave an increase of about 10 hundredweights of commercial tomatoes, whereas 200 pounds of P_2O_5 per acre raised yields nearly 20 hundredweights over the 100-pound P_2O_5-per-acre treatment (treatment 5 minus treatment 3). The percentage of culls rose slightly when 100 pounds of P_2O_5 per acre were used and then decreased somewhat more with 200 pounds of P_2O_5 per acre. The mean weight of commercial fruit showed no appreciable change attributable to phosphate applications. The total weight of tomatoes produced per acre responded significantly only to the application of 200 pounds of P_2O_5 per acre.

The use of phosphate fertilizers for tomato production in Coto clay soils seems to be essential. This need of phosphate fertilizers in Coto clay has been demonstrated for other crops also, such as sugarcane (2), red beans (4), potatoes (3), eggplants (7), cucumbers (6), and corn (8). This high demand for phosphorus has also been observed in other areas for short-growing crops.

POTASSIUM

Potash fertilizers produced no significant increase in yield of tomatoes. This was true for commercial fruit, culls, and total production per acre. This lack of response of the Coto clay to potash applications has been noted before for sugarcane (2), potatoes (3), red beans (4), and cucumbers (6).

FILTER-PRESS CAKE

Filter-press cake, an organic byproduct from the sugar mills of Puerto Rico, proved to be of definite value in fertilizing tomatoes grown on a Coto clay. When used alone, 10 tons of the filter-press cake per acre increased total tomato yield in a barely significant way over that of the no-fertilizer treatment (treatment 9 minus treatment 8). However, with 20 tons of filter-press cake per acre, significant yield increases of commercial tomatoes of 22 hundredweights were realized (treatment 10 minus treatment 8). With the use of filter-press cake alone, the mean weight of commercial fruit was reduced from 2.41 to 2.20 ounces (treatment 8 compared with treatment 10).

When combined with commercial fertilizer, filter-press cake gave impressive increases in yield of tomatoes per acre. The combination of 100 pounds of N and 200 pounds each of P_2O_5 and K_2O per acre with 20 tons of filter-press cake gave a yield increase of 21.2 hundredweights of commercial tomatoes per acre (treatment 12 minus treatment 2). The use of 10 tons of filter-press cake plus treatment 2 did not give any significant yield increases. The percentage of culls was reduced where the filter-press cake was used in combination with commercial fertilizer, and the mean weight of commercial fruit remained high.

The value of filter-press cake for growing tomatoes has been shown by other workers (5, 6). It should be stressed here that maximum benefit was realized from the filter-press cake as a fertilizer source because of the fact that the Coto clay did not need additional sources of potassium. Filter-press cake averages about 2.50 percent of N and P_2O_5 but contains only traces of K_2O. Since the tomatoes responded significantly to nitrogen and phosphate and not to potash fertilizers, the filter-press cake was proved to be a good fertilizer source for tomatoes on a Coto clay. On other soils which

require additional potash fertilizers the filter-press cake would have to be re-enforced with potash to give good results for tomatoes.

MAGNESIUM AND BORON

The application of the minor elements magnesium or boron as magnesium oxide and borax failed to produce any significant increases in yields. The use of 100 pounds of MgO per acre actually significantly reduced yields of commercial tomatoes 21.2 hundredweights (treatment 7 minus treatment 14). Neither percentage of culls nor mean weight of commercial fruit were appreciably influenced by the magnesium or boron treatments (compare treatments 13 and 14 with 7).

NUMBER OF APPLICATIONS

The application of the fertilizer in two portions instead of one did not produce any significant increase in yield of commercial tomatoes (treatment 15 minus treatment 7). The percentage of culls produced dropped from 43 with one fertilizer application to a low of 35 with two applications. There was no significant difference in mean weight of fruit attributable to the two fertilizer applications.

The Coto clay has high permeability (2) and water drains through this soil very rapidly. This high permeability, coupled with the high rainfall and irrigation may, however, leach out some of the fertilizer nutrients applied to the soil and a split application of fertilizer may possibly be a better practice on Coto clay.

PRACTICAL RECOMMENDATIONS

For the Plamar variety of tomatoes growing on a Coto clay in Puerto Rico the following fertilizer recommendations may be followed:

Nitrogen: 100–150 pounds of N per acre.
Phosphorus: 150 to 200 pounds P_2O_5 per acre.
Potassium: 0–50 pounds of K_2O per acre.
Filter-press cake: 15–20 tons per acre.

The filter-press cake should be applied in the hole at the time of planting.

SUMMARY

The use of various fertilizer treatments on the Plamar variety of tomatoes growing on a Coto clay at the Isabela Substation revealed that:

1. The use of 100 pounds of N per acre gave significantly higher yields of commercial tomatoes per acre than either none or 200 pounds of N per acre.

2. Phosphate fertilizers increased tomato yields, the highest yields being obtained with 200 pounds of P_2O_5 per acre.

3. There was no response to potash fertilizers.

4. The use of 20 tons of filter-press cake per acre gave significant increases in yields over the no-fertilizer treatment.

5. When 20 tons of filter-press cake were used combined with 100 pounds of N and 200 pounds each of P_2O_5 and K_2O per acre, the yields obtained were superior to those when the filter-press cake or chemical fertilizer were used alone.

6. No yield increases were obtained with magnesium and boron additions to the N-P-K fertilizer applications.

RESUMEN

Se compendia, a continuación, los resultados obtenidos del uso de varios tratamientos de abono aplicados a siembras experimentales de tomate, variedad Plamar, en un suelo del tipo Coto arcilloso en la Subestación Experimental de Isabela.

1. La aplicación de 100 libras de nitrógeno por acre produjo significativamente mayores rendimientos de tomates comerciales por acre, que cuando no se aplicó nitrógeno o se aplicó este elemento a razón de 200 libras por acre.

2. El uso de abonos fosfatados aumentó la producción de tomates, obteniéndose los mayores rendimientos cuando se aplicaron 200 libras de P_2O_5 por acre.

3. La cosecha no respondió a las aplicaciones de potasa.

4. La aplicación de cachaza a razón de 20 toneladas por acre, motivó aumentos significativos en los rendimientos, al compararse con los tratamientos en los cuales no se usó abono alguno.

5. Cuando se combinaron 20 toneladas de cachaza con 100 libras de nitrógeno por acre o con 200 libras de P_2O_5 y K_2O por acre, los rendimientos fueron superiores comparados con los tratamientos que recibieron cachaza o abonos químicos solamente.

6. No se obtuvieron aumentos en los rendimientos con la adición de magnesio o boro a los abonos químicos (N-P-K).

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Influence of Fertilizers on the Components of Available Sucrose-Percent-Cane

George Samuels[1]

INTRODUCTION

The influence of fertilizers on sugarcane tonnage has received much attention, and the literature on sugarcane abounds with details concerning this influence. There is not, however, very abundant information concerning the influence of fertilizers on the sucrose content of sugarcane. Most of the data available are concerned primarily with the gross effect of the fertilizer on sucrose-percent-cane without revealing the influence of the fertilizer on the factors upon which the available sucrose-percent-cane depends, such as polarization, Brix, or percentage of extraction.

These factors have more than passing interest to the staff of sugar factories whose task it is to obtain the highest yield of sugar from each ton of cane delivered to the mill. Such terms as extraction, Brix, and polarization may be abstract values to some cane growers, but they mean profit or loss to the factory man.

The object of this paper is to determine the influence fertilizers exert on the components of the available sucrose-percent-cane—polarization, Brix, and percentage of extraction. By revealing certain trends, it is hoped that a clearer picture may be obtained of the role of fertilizers and soil fertility in influencing the performance of sugarcane in the factory. An attempt is also made to show what portion of a factory performance by a cane should be credited to fertility influences and what portion to such factors as variety and climate.

PROCEDURES

The data used for determining the influence of fertilizers on polarization, Brix, and percentage of extraction were obtained from sugarcane-fertilizer field experiments conducted by the Agronomy and Horticulture Department of the Agricultural Experiment Station of the University of Puerto Rico. Only those experiments which showed statistically significant effects from the use of fertilizer on the available sucrose-percent-cane were utilized in this work to determine the influence of the fertilizer on the individual components.

The experiments were laid out using split-plot, simple, randomized-block,

[1] Agronomist, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R. The author wishes to thank B. G. Capó, Associate Director for Research, for his comments and suggestions on this work.

and triple-lattice designs. The majority of the experiments were replicated nine times; only two experiments had a minimum of six replications. The cane was cut as in commercial practice. Ten whole stalks of cane minus the tops were taken at random from each plot at the time of cutting. These canes were tagged as to origin, and were later ground in the hydraulic mill of the Agricultural Experiment Station at Río Piedras for determination of the sucrose content. All canes sampled were milled not later than 24 hours after cutting.

A hydraulic Squier mill was used which had two rollers, each one of which measured 12 by 16 inches. These rollers averaged 6.4 revolutions per minute, using a 10-horsepower Westinghouse electric motor, (1).[2] The rollers exerted a pressure of 29 tons per square inch for the extraction of the juice from the cane passing through them.

The following procedures were used for the determination of available 96° sucrose in the cane samples:

1. The 10-cane sample was weighed.
2. The cane sample was milled once and the bagasse also passed through once.
3. The juice obtained was weighed, and a representative sample taken for Brix and polarization.
4. Polarization and Brix were determined in the juice sample with a Baush and Lomb polariscope and a Zeiss refractometer.
5. Available 96° sugar in the juice was calculated by using the following formula:

$$\text{Available 96° sucrose-percent-cane} = \left(\frac{0.380329 \times \text{polarization}}{\text{Specific gravity } 20°/20°} - 0.41667 \text{ Brix}\right) \times \text{percent extraction}$$

The term "polarization" as used herein refers to the value determined by direct polarization of the normal-weight solution in a polariscope.

"Brix" or "degree Brix" as used herein is the percentage of solids dissolved in the juice as calculated from the index of refraction of the juice.

The term "percent-extraction" or "extraction" refers to the percentage of undiluted cane juice extracted from the cane sample by passing it through the hydraulic mill as described in step 2 of the procedures mentioned above. The weight of juice obtained divided by the weight of the sample milled and the quotient multiplied by 100 gives the percent-extraction. This term is not the same, but is comparable to the term "mill-extraction" used in the factory.

"Purity" is defined as the value obtained by dividing the sucrose in the juice by the degree-Brix and multiplying the quotient by 100.

[2] Numbers in parentheses refer to Literature Cited, p. 91.

RESULTS

It is to be remembered that the results presented here are based on experiments wherein various fertilizer treatments produced significant influence on the yield of available sucrose-percent-cane. Those experiments in which no significant effect on available sucrose-percent-cane was evidenced were not utilized in this study, as it was reasoned that, if the total product, available sucrose-percent-cane, remained uninfluenced by the fertilizer treatment, it was very improbable that its various components could have been significantly influenced, even though in opposite ways. Therefore, the results should not be interpreted to mean that the mere use of a particular fertilizer element will produce the effect found here. Only when the fertilizer significantly influenced available sucrose content (2) were these effects obtained.

TABLE 1.—*The influence of fertilizers on available-sugar components*[1]

Treatment No.	Fertilizer treatment, per acre of —			Available 96° sugar juice	Available 96° sugar in cane	Polarization	Brix	Extraction	Purity	Relative cane tonnage yields
	N	P_2O_5	K_2O							
					Nitrogen[2]					
	Pounds	*Pounds*	*Pounds*	*Percent*	*Percent*	*Degree*	*Degree*	*Percent*	*Percent*	*Percent*
1	0	300	300	16.39**	11.71**	68.8**	18.9**	71.4*	86.5**	52**
2	125	300	300	17.56	12.68	73.7	19.8	72.2	88.4	83**
3	250	300	300	17.66	12.75	74.1	20.0	72.4	88.0	100
					Phosphorus[3]					
4	300	0	300	15.71*	11.41*	67.8	19.1	72.4	82.0*	82**
5	300	150	300	16.39	12.03	69.8	19.4	73.3	84.4	98
6	300	300	300	16.40	11.93	70.4	19.8	72.7	82.7	100
					Potassium[4]					
7	300	300	0	15.09**	11.17**	68.7**	19.7**	69.9	81.3**	88**
8	300	300	150	16.77	11.67	71.2*	20.0	69.6	83.8	97
9	300	300	300	16.98	11.87	72.7	20.2	69.9	83.9	100

[1] The asterisks used in the table indicate that the treatment used significantly decreased the value as compared to that value for the treatment which follows: * indicates significant decrease at the 5-percent level, ** indicates significant decrease at the 1-percent level.

[2] Average of 10 experiments.

[3] Average of 5 experiments.

[4] Average of 8 experiments.

NITROGEN

Where the available sucrose-percent-cane was increased by the nitrogen applications, there was also an increase in polarization, Brix, purity, and percent-extraction (table 1). The average increase in polarization and Brix was highly significant to the first increment of nitrogen application to the soil (125 pounds N per acre) over the no-nitrogen treatment. The use of 250 pounds of per acre instead of 125, however, did not give any appreciable increase (table 1) although cane yields were significantly increased up to the 250-pound-N-per-acre level.

PHOSPHORUS

The phosphorus-deficient cane showed significantly lower values in available sugar in juice and cane, purity, and relative yields (table 1). Variations in phosphorus applications did not significantly influence polarization, Brix, or extraction.

POTASSIUM

Significantly lower values were obtained for all factors except percent-extraction when potash fertilizers were not used (table 1). Polarization values were affected strongly and gave significant increases at all fertilizer levels. Percent-extraction showed a smaller variation for different potassium levels than it did for either nitrogen or phosphorus.

DISCUSSION

When fertilizers had a significant influence on the available sugar content of the sugarcane, this influence was usually manifested in all of the components of sugar rather than in any one single component. In table 2, the relative responses of the components of sugar were compiled, based on the data of table 1. The no-fertilizer treatment of each of the three fertilizer elements was used as a base of 100, and all subsequent increases or decreases were computed on this basis. It may be seen that of the components which were used to calculate available 96° sugar, the polarization and Brix values were influenced to a greater extent than were percent-extraction and purity. The available 96° sugar in juice and in cane showed a degree of response quite similar to polarization values for all three fertilizer elements (N, P, K).

The response of the components of available sugar to nitrogen fertilizers was favorable in the experiments utilized in this study. As can be seen from the relative cane yield, last column of table 1, the no-nitrogen cane (treatment 1) produced a severe deficiency of nitrogen as evidenced by relative yields, which declined to almost one-half that of the high-nitrogen treat-

TABLE 2.—*The relative responses of the components of available sugar to fertilizer treatments*

Fertilizer treatment in pounds per acre of —			Available 96° sugar in juice	Available 96° sugar in cane	Polarization	Brix	Extraction	Purity
N	P_2O_5	K_2O						
				Nitrogen				
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	300	300	100	100	100	100	100	100
125	300	300	107	108	107	105	101	102
250	300	300	108	109	108	106	101	103
				Phosphorus				
250	0	300	100	100	100	100	100	100
250	150	300	105	105	103	102	99	103
250	300	300	105	105	104	104	100	103
				Potassium				
250	300	0	100	100	100	100	100	100
250	300	150	105	105	103	102	99	103
250	300	300	106	106	106	103	100	103

ment (treatment 3). Where relative cane yields were 83 percent (treatment 2), the various sugar components gave no significantly different values from the high-nitrogen treatment (treatment 3).

But for phosphorus and potassium, with relative cane yields of 82 and 88 percent, respectively, the no-P_2O_5 and no-K_2O treatments (treatments 4 and 7) had significantly lower values in the sugar components as compared with the high-fertilizer treatments (treatments 6 and 9). From a standpoint of relative cane yields deficiencies in phosphorus and potassium would make themselves felt in the components of available sugar before a nitrogen deficiency did so. In most cases in normal commercial practice, such severe nitrogen deficiencies as were developed under these experiments would not be encountered. In general, as evidenced by these data, one might expect the order of influence of the magnitude of a deficiency on available sucrose-percent-cane to be potassium > phosphorus > nitrogen.

The data so far reveal that fertilizers do influence the sugar content of cane and its component factors. However, it would not be fair to leave the impression that fertilizers alone exert a powerful influence on sugar content. Such factors as weather, variety, and soil should be considered, for they also exert strong influences on sucrose content. At times the influence of

TABLE 3.—*The influence of fertilizers, varieties, weather, and soil on the components of available-sugar and cane yields*

Item	Available 96° sugar in juice	Available 96° sugar in cane	Polarization	Brix	Extraction	Purity	Cane yields per acre
			Fertilizer[1]				
	Percent	*Percent*	*Degree*	*Degree*	*Percent*	*Percent*	*Tons*
0 K_2O	15.12	10.31	67.6	20.3	68.2	74.5	50
150 pounds K_2O	16.53	10.91	71.7	20.7	66.0	79.9	55
300 pounds K_2O	16.60	11.02	72.7	21.1	66.4	78.7	53
			Weather[2]				
Plant cane	16.60	11.02	72.7	21.1	66.4	78.8	53
Third ratoon	16.44	11.64	70.2	19.7	69.0	83.4	54
Fourth ratoon	17.93	12.41	76.2	20.7	69.2	86.4	53
			Varieties[3]				
M. 28	16.95	12.22	71.2	19.7	72.1	86.0	34
P.O.J. 2878	15.24	10.96	65.7	18.9	71.9	80.6	42
P.R. 902	17.17	12.07	72.0	19.8	70.3	86.7	62
			Soil and weather[4]				
Coto clay	15.24	10.96	65.7	18.9	71.9	80.6	42
Coloso silty clay	17.93	12.41	76.2	20.7	69.2	86.6	53
Fraternidad clay	14.50	10.47	67.8	19.7	72.2	73.6	33
Vía silty clay	17.44	12.26	73.6	20.1	70.3	86.8	41

[1] Variety P.O.J. 2878, second ratoon, at Arecibo; all treatments received 250 pounds N and 300 pounds P_2O_5 per acre.

[2] Variety P.O.J. 2878, at Arecibo; all treatments received 250 pounds N and 300 pounds P_2O_5 and K_2O, per acre.

[3] Third ratoon, at the Isabela Substation, all varieties received 250 pounds N and 300 pounds P_2O_5 and K_2O, respectively, per acre.

[4] Variety P.O.J. 2878; all soils received 250 pounds N and 300 pounds P_2O_5 and K_2O, per acre.

weather, soil, or variety may mask the influence of fertilizers on sugar content. Examples of the influences of fertilizer, weather, soil, and variety on sugar and components are given in table 3. The data were taken from field experiments, and so compiled that the only stated factor was the variable and all other experimental conditions were kept as constant as possible. One can readily see that variations as great as, or greater in magnitude than those obtained with fertilizers were obtained with such factors as

varieties, soil, and weather. Therefore, all data concerning the influence of fertilizers on sugar and its components must be evaluated carefully to insure that such factors as variety, soil, and weather are not responsible for the influence found or cited.

SUMMARY

Using data from experiments where fertilizers had significantly influenced available sucrose-percent-case yields, the influence of the fertilizers on the various components of sugar in sugarcane were found to be as follows:

1. When sufficient potassium was present, nitrogen applications increased polarization and degree-Brix very significantly, and percent-extraction to a lesser degree.

2. A deficiency of phosphorus significantly decreased sucrose both in juice and in cane, as well as purity.

3. Potassium deficiencies produced highly significant reductions in available sugar in juice and cane, polarization, Brix, and purity. Percent-extraction was not significantly influenced by use of potash fertilizers.

4. The relative responses to the fertilizer treatments were highest for available sugar in both juice and cane, and in polarization, with degree-Brix following. Percent-extraction showed the lowest relative response to the use of fertilizer.

5. The roles of weather, soils, and variety as compared to fertilizers in influencing sugar and its components are discussed, because their effects must be distinguished from the influence of fertilizer.

RESUMEN

Cuando se usaron datos demostrativos de que los abonos influían significativamente sobre el por ciento de sacarosa en los rendimientos de la caña de azúcar, se encontró que la influencia de estos abonos sobre los varios componentes del azúcar fué como sigue:

1. Cuando hubo suficiente potasio presente, las aplicaciones de nitrógeno aumentaron muy significativamente la polarización y el grado de Brix. La presencia de potasio influyó en un grado menor en cuanto al por ciento de extracción.

2. Una deficiencia en fósforo redujo significativamente la sacarosa, tanto en el jugo como en la caña y también aminoró la pureza del jugo.

3. Las deficiencias en potasio produjeron reducciones altamente significantes en el azúcar disponible en el jugo y en la caña, en la polarización, en el grado de Brix y en la pureza del jugo. El por ciento de extracción no fué afectado significativamente por el uso de los abonos potásicos.

4. El grado relativo de responder a los tratamientos con abonos fué

más alto en cuanto al azúcar disponible, tanto en el jugo como en la caña, y en la polarización, siguiendo en este respecto el grado de Brix.

5. Se discutieron los efectos del clima, de los suelos y de las variedades en lo que se refiere a su influencia sobre la producción del azúcar y la variación de sus componentes, porque debe distinguirse de la que ejerce el abono.

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Influence of Preharvest Sprays with Maleic Hydrazide on the Sprouting of Potatoes

Héctor Cibes, George Samuels, and Juan P. Rodríguez[1]

INTRODUCTION

Although the potato (*Solanum tuberosum L.*) is not native to Puerto Rico, it is widely consumed in the Island. For the most part, it has been imported from the United States. Though the potato can be grown here commercially, it has not been planted extensively because of disease problems (blights and virus diseases) and the premature sprouting of the seed potatoes before planting.

The disease problem has largely been solved by the use of the blight-resistant variety Kennebec introduced into Puerto Rico by the Agricultural Experiment Station, Río Piedras (1).[2] However, the premature sprouting of the tubers remains a serious problem because the proper seed pieces for planting cannot be maintained and fresh imports from the United States must be made annually.

Sprouting is also troublesome to the grocery storekeeper in that it causes loss of saleable tubers when potatoes are stored for any length of time before sale.

With these facts in mind research was initiated to determine whether any chemical treatment might be used to inhibit sprouting of potatoes in storage.

PROCEDURE

A field of the Kennebec variety of potato growing on a Vía clay at Aibonito was used to test the preharvest application of maleic hydrazide for determining its influence on the sprouting of potatoes in storage. Maleic hydrazide was applied at concentrations of 0.25, 0.50, and 1.00 percent in spray form on the potato foliage at intervals of 6, 4, and 2 weeks before harvesting the crop, beginning October 15, 1952. The plot-size used was 4 rows, 2½ feet apart and 20 feet long, or one two-hundred-eighteenth of an acre. Each plot was inclosed by portable plywood shields when being sprayed to prevent drifting of the spray material to adjacent plots.

Potato samples of 25 pounds each were obtained after harvest from the differently treated plots, placed in 50-pound open-weave fabric bags, and

[1] Associate Plant Physiologist, Agronomist, and Associate Agronomist, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[2] Numbers in parentheses refer to Literature Cited, p. 99.

stored at temperatures of 45° and 68° F. in controlled cold storage chambers. The number of tubers which had sprouted was ascertained after 6 months storage.

RESULTS

The results on the influence of maleic hydrazide preharvest sprays on the yield and sprouting of the potato are given in table 1.

EFFECTS ON YIELD AND SHAPE OF TUBERS

The application of maleic hydrazide 6 weeks before harvesting the crop, and at any of the concentrations used, had a marked detrimental effect on the yields. The yield differences between these plots and plots similarly treated later in the growing season were highly significant. In fact, yields were reduced 71 percent when plots were sprayed 6 weeks before harvesttime as compared to 4 or 2 weeks.

The reduction in yield in these plots was apparently produced by a reduction in the size of the tubers. It was observed that a considerable number of the tubers were very small. Some of them were the size of a cherry. This condition bore some relation to the concentration of the maleic hydrazide used. Plants sprayed with a 1-percent solution usually produced tubers of smaller size than plants sprayed with a 0.5-percent solution, and these, in turn, produced smaller tubers than those receiving a 0.25-percent maleic hydrazide spray. This may explain why there was a tendency, within the above-mentioned time of treatment, for the yields to decrease somewhat with an increase in the concentration of the maleic hydrazide in the spray solution.

The various maleic hydrazide treatments applied 6 weeks before harvesttime not only affected the yields of the experimental plots, but also affected the shape of the tubers. Tubers harvested in these plots had protuberances all over their surface; there was also some cracking. The malformation was attributed to secondary growth.

Apparently the number of tubers set per plant under these various treatments was not affected. On the contrary, it was observed that the number of tubers was higher in plots which were sprayed with the highest concentration of the chemical than in plots treated otherwise. These were also the plots that produced the smallest potatoes.

According to the data presented in table 1 there were no significant differences in yields between potato plots treated 4 or 2 weeks before the crop was harvested, regardless of the concentration of the chemical used in the spray solution. No distortion in shape of the tubers could be detected at these two times, nor did the tubers exhibit any cracking; they also appeared to be of normal size.

TABLE 1.—*Influence of various concentrations of maleic hydrazide sprays, and time intervals of application, on the yields and sprouting of potatoes of the Kennebec variety when stored at 45° and 68°F.*

Treatments		Yield of potatoes per acre	Potatoes sprouted when stored at	
Time of application before harvest (weeks)	Concentration of maleic hydrazide		45° F.	68° F.
	Percent	*Cwt.*	*Percent*	*Percent*
6	0.25	25.7	37	47
	.50	14.6	24	47
	1.00	9.4	7	24
Mean		16.6	23	39
4	0.25	56.0	6	27
	.50	60.4	15	46
	1.00	57.3	19	36
Mean		57.8	13	36
2	0.25	61.0	33	55
	.50	56.0	38	58
	1.0	56.0	30	45
Mean		57.6	34	53
0 (control)		79.6	48	75
Mean of all chemical treatments		44.0	23	43
Mean of all storage temperatures		—	26	46
Least significant difference needed between means of time of application treatments:				
5-percent level		16.6	25	25
1-percent level		23.5	40	40
Least significant difference needed between means of all chemical treatments and control:				
5-percent level		13.1	7	7
1-percent level		20.1	10	10
Least significant difference needed between means of 2 storage temperatures:				
5-percent level				10
1-percent level				13

Table 1 also shows that plots treated with maleic hydrazide 4 or 2 weeks before the crop was harvested yielded significantly less at the 5-percent level than plots which received no chemical treatment at all. However, the differences between these same plots were not significant at the 1-percent level. This shows that although the detrimental effect of maleic hydrazide was considerably reduced by spraying late in the growing season, it was not completely compensated for by the late application.

EFFECT ON GROWTH AND APPEARANCE OF PLANTS

Maleic hydrazide also affected the growth and appearance of potato plants. Application of maleic hydrazide, regardless of the time of application and the concentration used, resulted in dieback of plants and development of a chlorotic condition. However, the time of application and the concentration of the chemical in the spray solution greatly modified the intensity and the extent of the injury. The higher the concentration of the maleic hydrazide and the earlier it was applied to the plants, the more severe the injury.

In general, the first abnormality to appear, 2 weeks after the plants were sprayed, was a chlorosis. The plants at first showed a slight discoloration. After some time they turned completely yellow. In severe cases, as when the plants were sprayed with the highest concentration 6 weeks prior to harvest, they showed severe dieback of the shoots and burning of the younger leaves. These plants tended to produce lateral shoots from the axillary buds below the injured portion; these new branches gave the plants a bushy appearance.

EFFECT ON SPROUTING OF STORED TUBERS

On the other hand, maleic hydrazide had a beneficial effect in preventing the sprouting of the tubers in storage. When, for example maleic hydrazide was applied at the rate of 1 percent 6 weeks before the harvest, sprouting was reduced significantly in storage. However, the fact that yields were so drastically reduced, and that the tubers were malformed, nullified the otherwise beneficial effect of the chemical treatment in preventing sprouting.

Application of maleic hydrazide at the various concentrations 2 weeks before harvesttime resulted in a high percentage of sprouted tubers at both temperatures. It seems probable that, at this stage of growth, so close to harvesting the crop, the absorption of maleic hydrazide through the leaves was too slow, and the time permitted for its absorption too short. Therefore, the commercial application of maleic hydrazide that late in the growing season is not warranted.

The best results were obtained from the sprout-inhibition standpoint when maleic hydrazide was applied 4 weeks before the end of the field experiment. At this time of application the sprouting of tubers in storage was considerably reduced as compared to the control and other treatments. At this time of treatment a concentration of 0.25 percent of maleic hydrazide gave the best results. When stored at 45° F. these tubers showed only 6-percent sprouting and, at 68° F., the sprouting was 27 percent.

Temperature itself had a marked effect on the sprouting of tubers. Regardless of the time of application or the concentration of maleic hydrazide solution used, the sprouting of potatoes was significantly lower in storage at 45° F. than at 68° F.

DISCUSSION

From the foregoing results it seems that yields of potatoes are more affected by the time at which maleic hydrazide is applied to the plant than by the concentration. Apparently maleic hydrazide should be applied when the tubers are all set and making good growth. Otherwise most of them will remain small and malformed.

Similar results have been obtained by other investigators with the potato and bulbous plants. Denisen (2), using the same Kennebec variety, found that yields declined drastically with increased concentration after a prebloom application. On the other hand, full-bloom sprays resulted in less decreased yield for the respective concentrations. The treatments applied at the bloom-drop stage gave no yield reduction at all.

Moreover, Barnard and Warden (3) found that 0.1-percent maleic hydrazide applied early in the season for the control of weeds in a potato plantation depressed yields by 12 percent, slightly increased tuber set, and reduced the size of the tubers. The use of 0.5-percent maleic hydrazide reduced yields by 83 percent, increased tuber set by 124 percent, and lowered the size of No. 1 potatoes 45 percent.

Furthermore, Wittwer and Paterson (4), working with onions, obtained similar results. Onion plants treated with maleic hydrazide too early in the season produced hollow or puffy bulbs. These authors recommended that onion plants should be treated when the bulbs had matured but still had green tops, usually 1 to 2 weeks before harvest.

Greulach (5) found marked differences in the growth of tomato plants sprayed with various concentrations of maleic hydrazide. He found that all plants treated when they were 3 weeks old had higher shoot:root ratios than the controls. The extremely high shoot:root ratio of the plants treated when 3 weeks old was particularly noteworthy.

In attempting to explain these differences in the shoot:root ratios he pointed out that the inhibition of root growth was caused by the inter-

ference of maleic hydrazide with the translocation of food in the plants. This was indicated by: (1) The high water content of the roots, (2) the relatively low water content of the shoots of treated plants, (3) the fact that maleic hydrazide collapsed the phloem elements in cotton plants, (4) the extremely slow translocation of starch from the leaves of treated plants, and (5) reports of accumulation of food in the leaves of plants treated with maleic hydrazide.

It is possible that, as in the tomato and other woody plants, the application of maleic hydrazide to potato vines interferes with the translocation of food material to the roots. This may account for the small size of the tubers. It also may be possible that, at this early stage, absorption of maleic hydrazide by plants is so high, and its translocation to and concentration in the roots is such that it may interfere with the development of the tubers. It has been found that young plants and plants treated with maleic acid at the start of the growing season are more susceptible to maleic hydrazide than older plants or plants treated later in the growing season.

The time of application also interfered with the sprouting of the tubers in storage. The early and midseason applications controlled sprouting effectively when the tubers were stored at 45° F.; the late application of the chemical had very little effect on sprouting. Wittwer and Paterson (4) made similar observations on Irish Cobbler and Pontiac potato varieties when sprayed with 0.1- to 0.25-percent solutions of maleic hydrazide a few days to a week before harvest. Sprouting of stored tubers was not completely delayed under these treatments. However, vines sprayed with 0.1 percent displayed almost complete sprout inhibition if the spray was applied when the tubers were immature and about 1 to 2 inches in diameter. This proved true even when the potatoes were stored at 55° F.

Results similar to these have been obtained with hormonelike substances. Ellison and Smith (6) found that the methyl ester of naphthaleneacetic acid applied in July controlled sprouting better in storage than did later applications. August application reduced sprouting significantly as compared with the check. No sprouting inhibition was associated with September applications.

The statistical analyses of the data obtained in this experiment show that there was no significant relationship between reduction of yield and the various maleic hydrazide concentrations, when time of application was disregarded. However, the concentration apparently affected the sprouting of the tubers in storage, especially when at 45° F. temperature.

When the application was made 6 weeks before harvesttime sprouting of tubers decreased as the concentration of the maleic hydrazide was increased. On the other hand, the reverse occurred when the various concentrations of the chemicals were sprayed on plants 4 weeks before they were

harvested. In this particular case the extent of sprouting was directly proportional to the concentration of the maleic hydrazide used.

Maleic hydrazide can affect the morphology and other physiological changes in plants. Responses similar to those described for potato varieties in this paper have been observed by Mikkelsen, Griffith, and Ririe (7) in the sugar beet, and by Craft (8) in numerous other plants. The senior author has observed abnormal formative effects to be induced by maleic hydrazide in various tropical plants such as sugarcane, sweetpotato, yams, and tobacco.

SUMMARY

1. The application of maleic hydrazide 6 weeks before harvesting the crop at any one of the concentrations used—0.25, 0.50, and 1 percent—had a marked detrimental effect on yields of potatoes. A considerable proportion of the tubers in these plots were small and malformed.

2. There were no significant differences in yields between potato plants treated 4 and 2 weeks before the crop was harvested.

3. Such plots yielded significantly less where sprayed at the 5-percent level than did the control plots.

4. Application of maleic hydrazide, regardless of time of application and concentration, resulted in dieback of plants and the development of a chlorotic condition.

5. The best results from the standpoint of sprout inhibition were obtained when 0.25-percent maleic hydrazide was applied to potato plots 4 weeks prior to harvesttime.

6. Regardless of time of application or concentration of the maleic hydrazide, the sprouting of potato tubers was significantly lower at 45° than 68° F.

RESUMEN

Los resultados de la aplicación de la hidrazina del ácido maleico y sus efectos sobre la germinación de la papa se informan como sigue:

1. Cuando se aplicó la hidrazina del ácido maleico, sin importar la concentración a que fué usada, 6 semanas antes de la cosecha de papas, este compuesto químico tuvo efectos desventajosos sobre los rendimientos. Los tubérculos obtenidos de los predios tratados, en su gran mayoría fueron pequeños y deformes.

2. No hubo diferencias significativas entre los rendimientos de las plantas tratadas 4 y 2 semanas antes de efectuarse la cosecha. Sin embargo, al ampliar el análisis estadístico se vió que los predios tratados 4 y 2 semanas antes de la cosecha rindieron significativamente menos, al 5 porciento, que los predios sin tratar (check plots).

3. Siempre que se aplicó la hidrazina del ácido meleico, sin importar la concentración usada, causó marchitez y clorosis en las plantas.

4. En cuanto a la inhibición a germinar, el mejor tratamiento con la hidrazina resultó ser el que se aplicó al 0.25 por ciento, 4 semanas antes de la cosecha.

5. Sin tomar en cuenta el grado de concentración de la hidrazina ni la época de su aplicación, el porciento de germinación de la papa fué significativamente menor a una temperatura de 45° F. que a los 68° F.

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Effect of Spacing and Fertilization on the Yield of Potatoes

Pablo Landrau, Jr., Juan Pastor Rodríguez, George Samuels, Severiano Alers Alers, and R. Gandía Caro[1]

INTRODUCTION

At present the cultivation of potatoes in Puerto Rico is limited to a small acreage. The Island of Puerto Rico imports practically all of the potatoes that it consumes. During the years 1952 and 1953, it imported 735,379 and 914,913 one-hundred-pound bags of potatoes, respectively. The yields of the varieties tested and cultivated in the Island during the past 10 years were so low that their production on a commercial scale was economically impossible. This low yield was due principally to the susceptibility of the potato varieties to early and late blight. Recently the introduction of the Kennebec variety, which proved resistant to both early and late blight, rendered the possibility of growing potatoes commercially on the Island so important that there was need to gather information about the quantities of the major fertilizer elements (N-P-K) required to obtain maximum production from soils devoted to the crop. It was decided also to determine the best distance between plants, and whether closer spacing required higher rates of fertilizer.

EXPERIMENTAL PROCEDURE

The spacing and fertilizer study with potatoes consisted of three experiments in different areas of the Island which varied as to soil type, elevation, and amount of rainfall. The Corozal experiment, (elevation 400 feet) was conducted on a Lares clay, a lateritic acid clay (pH 4.5) of the terrace and alluvial fans of Puerto Rico, cropped mainly to sugarcane and pineapples. The Aibonito experiment (elevation 2,000 feet) was established on a Juncos clay, an acid soil (pH 6.5) of the foothills that occurs in association with the extensive Múcara soils of the mountainous area and also in association with the soils of the valleys. This soil is cropped to sugarcane, subsistence crops, and tobacco. The Isabela experiment (elevation 275 feet)

[1] Assistant Agronomist, Associate Agronomist, Agronomist, and Research Assistant in Agronomy, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R. The authors wish to express their appreciation to the following for their fine cooperation in the field: A. S. Amy, Associate Agronomist, in Charge; H. Gandia Díaz, Associate Horticulturist, in Charge; R. Olivencia, Research Assistant in Plant Breeding; A. Riollano, Agronomist, in Charge, and R. Abrams, Research Assistant in Agronomy, all of the Agricultural Experiment Station of the University of Puerto Rico.

was planted on a Coto clay, a friable soil of the coastal plains, slightly acid in reaction (pH 6), and devoted mainly to sugarcane and other irrigated crops, such as peppers, tomatoes, tobacco, cotton, and corn.

The spacing used in all the experiments were 6, 9, 12, 15, and 18 inches between plants. The fertilizer treatments for the three experiments consisted of varying amounts per acre of nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O). The rates applied per acre of these fertilizer substances are presented later in tables 1 to 3.

The Corozal experiment was planted on January 18, 1954, using plots of five rows, 2 feet apart and 20 feet long, or approximately one two-hundred-seventeenth of an acre in size. The fertilizer was applied in the hole and covered with soil 1 day before planting. The experiment was harvested on April 12, 1954, after 85 days of growth.

The Aibonito experiment was planted on December 16, 1953, and fertilized 12 days after planting. The fertilizer was applied in bands about 2 inches deep at a distance of 3 inches from the small potato plants. The plots consisted of four rows, 3 feet apart and 20 feet long, or approximately one eighty-one hundredth of an acre in size. The crop was harvested on March 29, 1954, after 104 days of growth.

The Isabela experiment was fertilized on December 30, 1953, and planted 6 days later. The fertilizer was applied in the hole and covered with soil. The plots consisted of five rows, 3 feet apart by 17 feet long, or approximately one one-hundred-seventieth of an acre in size. The crop was harvested on April 7, 1954, after 94 days of growth.

The experimental design for all these experiments was a split-plot one in which the spacing between plants was studied in the whole plots. All treatments were replicated four times.

The variety planted was Kennebec, a seedling introduced in Puerto Rico from the United States about 5 years ago. This seedling proved to be resistant to early and late blight, two serious diseases to which the varieties of potatoes previously tested in the Island proved susceptible.

The potatoes were treated with a solution of 2-chloroethanol, 60 ml. per gallon of water for 5 minutes, to increase the germinating power of the potato seed pieces by breaking the dormancy period. After the potato seed were treated, scattered on the floor, and allowed to dry, they were cut into small pieces. The size of seed depended on the number of eyes presented and the size of the potato itself. The scars made on the potatoes were allowed to heal, before planting.

EXPERIMENTAL RESULTS

The results of the effect of spacing and different fertilizer treatments on the yields of potatoes are presented in tables 1 to 3.

TABLE 1.—*Influence of spacing and major-element fertilizers on the yield of potatoes in the Corozal experiment on Lares clay*

Treatment No.	Treatments per acre of—			Mean yield of potatoes per acre for spacing indicated—					General fertilizer means
	N	P_2O_5	K_2O	6 in.	9 in.	12 in.	15 in.	18 in.	
	Pounds	*Pounds*	*Pounds*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*
1	0	100	100	63.8	53.7	55.7	51.6	45.3	54.0
2	100	0	100	52.3	54.0	37.8	35.6	33.6	42.6
3	100	100	0	61.6	64.1	66.2	61.8	37.1	58.2
4	100	100	100	95.0	51.7	63.6	62.2	55.2	65.5
5	150	150	150	75.7	55.6	59.7	59.7	67.2	63.6
6	200	200	200	78.6	58.9	57.6	54.4	54.6	60.8
General spacing means				71.2	56.4	56.8	54.2	48.8	

Least significant differences between:

	5-percent level	*1-percent level*
Any 2 general means of fertilizer treatments	13.4	17.8
Any 2 general means of spacing treatments	17.0	23.9
Any 2 means of individual fertilizer-spacing treatments	30.0	39.8
Any 2 means of any other spacing and fertilizer experiments	32.2	43.4

TABLE 2.—*Influence of spacing and major-element fertilizers on the yield of potatoes in the Isabela experiment on Coto clay*

Treatment No.	Treatments per acre of—			Mean yield of potatoes per acre for spacing indicated—					General fertilizer means
	N	P_2O_5	K_2O	6 in.	9 in.	12 in.	15 in.	18 in.	
	Pounds	*Pounds*	*Pounds*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*
1	0	100	100	154.0	150.5	142.7	120.9	108.2	135.2
2	100	0	100	128.9	124.4	97.7	96.1	69.2	103.3
3	100	100	0	168.6	160.4	148.1	136.0	124.5	147.5
4	100	100	100	197.3	158.6	185.1	150.2	145.0	167.2
5	150	150	150	189.6	168.6	141.1	129.5	109.0	147.6
6	200	250	200	173.1	160.3	155.5	129.7	110.0	145.7
General spacing means				168.6	153.8	145.0	127.1	111.0	

Least significant differences between:

	5-percent level	*1-percent level*
Any 2 general means of fertilizer treatments	24.0	31.7
Any 2 general means of spacing treatments	23.2	32.5
Any 2 means of individual fertilizer spacing treatments	53.7	71.3
Any 2 of any other spacing and fertilizer treatments	72.6	54.2

TABLE 3—*Influence of spacing and major-element fertilizers on the yield of potatoes in the Aibonito experiment on Juncos clay*

Treatment No.	Treatment per acre of—			Mean yield of potatoes per acre for spacing indicated—					General fertilizers means
	N	P_2O_5	K_2O	6 n.	9 in.	12 in.	15 in.	18 in.	
	Pounds	*Pounds*	*Pounds*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*	*Cwt.*
1	0	100	100	71.0	55.6	54.5	41.7	29.5	50.5
2	100	0	100	68.0	51.2	48.6	38.9	36.3	48.6
3	100	100	0	75.6	67.2	53.8	49.3	42.8	57.7
4	100	100	100	77.7	57.4	56.2	43.6	42.8	55.5
5	150	150	150	80.9	68.8	58.4	38.0	36.0	56.4
6	200	200	200	72.6	63.6	52.6	45.4	41.1	55.0
General spacing means				74.3	60.6	54.0	42.8	38.1	

Least significant differences between:

	5-percent level	*1-percent level*
Any 2 general means of fertilizer treatments	5.3	7.0
Any 2 general means of spacing treatments	7.5	10.5
Any 2 means of individual fertilizer spacing treatments	11.9	15.8
Any 2 means of any other spacing and fertilizer treatments	13.2	17.8

EFFECT OF MAJOR FERTILIZER ELEMENTS ON YIELDS

Nitrogen

In none of the three experiments did the applications of nitrogen have consistent significant effects on potato yields.

Phosphorus

There was a definite response in yield of potatoes from the use of phosphorus fertilizer. The use of 100 pounds of phosphorus (P_2O_5) per acre proved to be sufficient for all three experiments (see tables 1, 2, and 3, treatments 2 and 4). No additional response was obtained by increasing the phosphorus application beyond 100 pounds of P_2O_5 per acre. The response in yield was significant at the 1-percent level for the Corozal and Isabela experiments and at the 5-percent level for the Aibonito experiment.

Potassium

The application of potash failed to increase yields significantly in any one of the three experiments (see tables 1, 2, and 3, treatments 3 and 4).

The response of potatoes to the three major fertilizer elements for all three experiments is presented in a graphic form in figure 1. The Aibonito and Corozal experiments followed more or less the same trend in relation

to the response to phosphorus, then nitrogen, and last potassium. The potato made better use of all three fertilizer elements on the Coto clay soil at Isabela than on the Lares clay and the Juncos clay at Corozal and Aibonito, respectively.

EFFECT OF DIFFERENT PLANTING DISTANCES

The results of different planting distances are also presented in tables 1, 2, and 3. Spacing definitely influenced the yield of the potato.

The highest yields were obtained when the potatoes were planted at a distance of 6 inches between plants and decreased gradually as the planting distance increased. The highest yields were obtained when the potato seed pieces were planted 6 inches apart in the row in all three experiments; at Corozal a significantly higher yield was obtained at the 6-inch than at the 15- and 18-inch distances. At Aibonito the yields obtained at the 6-inch planting distance were highly significantly greater than those obtained at the other four spacings used (see table 3, general means). The yields obtained at Isabela showed that the 6-inch was superior to the 12-inch spacing at the 5-percent and to the 15- and 18-inch spacings at the 1-percent level (see table 2).

The high production of potatoes is influenced not only by the fertilizer

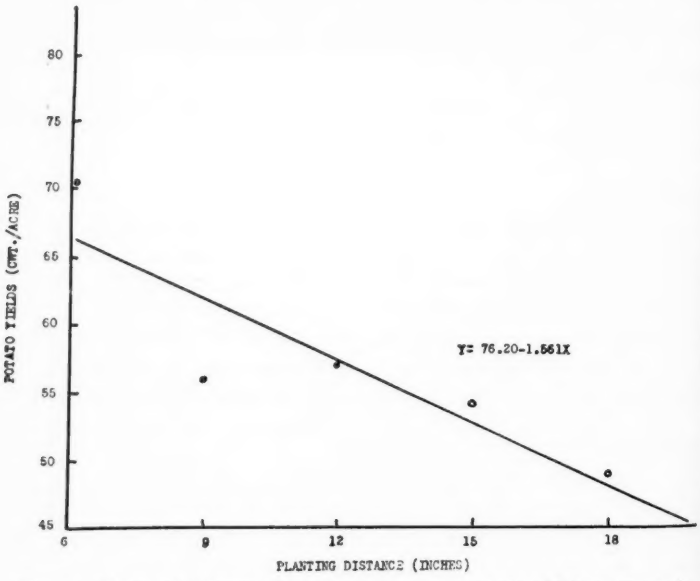

FIG. 1.—Effect of different planting distances on potato yields at Corozal.

used but also by the planting distance. The results of three spacing experiments are presented in figures 1, 2, and 3. The graphs show that a definite linear relationship exists between yields of potatoes per acre and the planting distance; the yields per acre decreased with increased distance of planting. The regression equations obtained were: For the Corozal experiment $Y = 76.20 - 1.561\ X$; for Isabela $Y = 197.85 = 4.731\ X$; and for Aibonito $Y = 90.07 - 3.008\ X$, where Y is the yield of potatoes in hundred-weights per acre and X is the spacing in inches between plants in the row. The regressions of distance of planting on yield of potatoes per acre were very significant at the 1-percent level in all three cases.

FERTILIZER-PLANTING DISTANCE INTERACTION

There were no significant interactions between planting distances and fertilizer applications. The potatoes planted at a distance of 6 inches did not require any more fertilizer than did those at the extreme distance of 18 inches, despite the fact that there were three times as many plants present at the closer planting distance. The use of additional fertilizer above the regular rates (treatments 5 and 6 as compared to treatment 4) did not lead to higher yields. It appears that, at least under conditions similar to

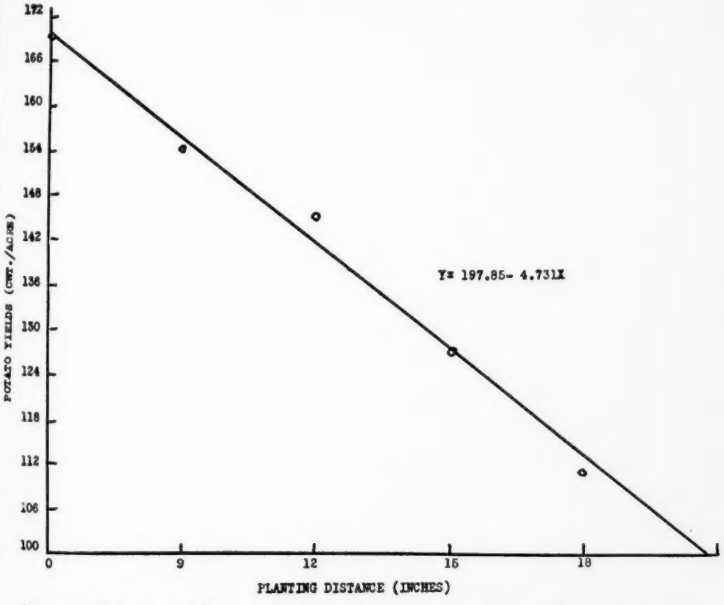

FIG. 2.—Effect of different planting distances on potato yields at Isabela.

those of these experiments, maximum yields would be obtained by using a 6-inch distance between plants in the row and applying only 100 pounds of P_2O_5 per acre.

RELATIVE RESPONSE TO FERTILIZERS AND SPACING

Potatoes, like all other crops, require plant food for their development and growth. The quantities of the different fertilizer elements that have to be applied to any soil depend on the actual amounts of these elements which the soil itself is able to provide to the crop. The available amounts of these elements in the soil depend on the quantities already present there, the chemical form in which they are present, and the weather during the growth period. Excessive drought or rainfall during the growth period is detrimental to the normal growth of the plant, even if the soil contains optimum amounts of the nutritive elements. Table 4 and figure 4 present the relative response of the potato to the fertilizer elements and the six different spacings in the form of percentage reduction in yields due to the omission of one fertilizer element or to increased spacing.

The calculations for reduction in yield caused by spacing were made by using the highest yields obtained, which corresponded to the 6-inch spacing, as the basis, and comparing these with the others included in the study.

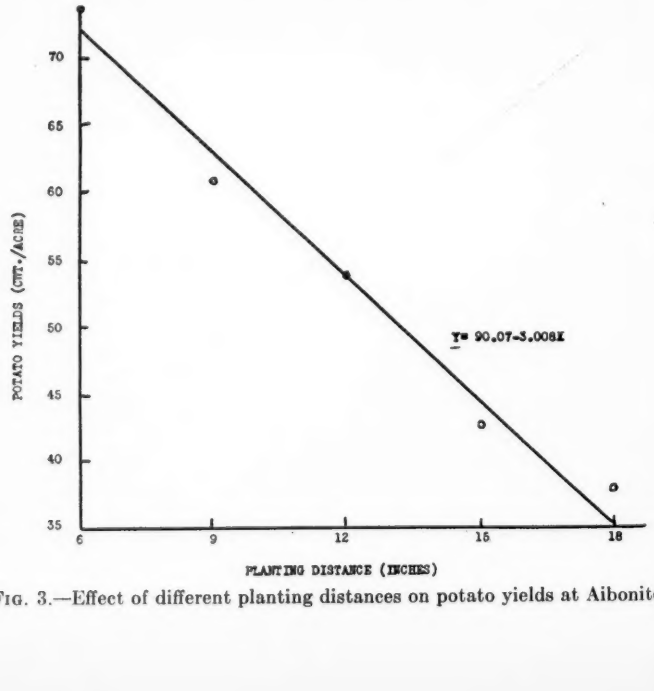

FIG. 3.—Effect of different planting distances on potato yields at Aibonito.

TABLE 4.—*The percentage reduction in yield of potatoes attributable to increased spacing or to the omission of nitrogen, phosphorus, or potassium*

Place of experiment	Reduction in yield due to spacing of—[1]					Reduction in yield from omission of—[2]		
	6 inches	9 inches	12 inches	15 inches	18 inches	Nitrogen	Phosphorus	Potassium
Aibonito	100	18.4	27.3	42.3	48.7	9.1	12.4	4.0
Corozal	100	20.8	20.2	23.8	31.4	17.5	34.9	11.2
Isabela	100	8.8	14.0	24.6	34.2	19.1	38.2	11.2
Mean for all places	100	15.6	20.5	30.3	38.1	15.2	28.5	6.3

[1] Percentage reduction based on general means for spacing and fertilizer.
[2] Calculations based on yields obtained on fertilizer treatments 1 to 4.

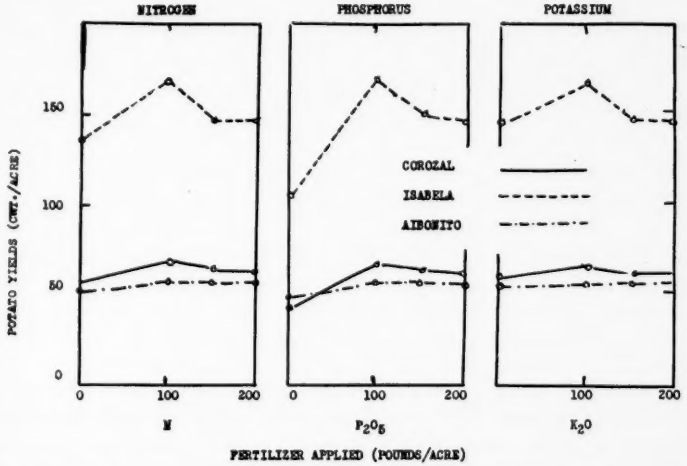

FIG. 4.—Yield response of the potato to nitrogen, phosphorus, and potassium when used as fertilizer at Aibonito, Corozal, and Isabela, on different soil types.

The reduction for the fertilizer was calculated from the yields of treatments 1 to 4.

As mentioned above, the greatest reduction in yield occurred when phosphorus was omitted, then nitrogen, and last potassium. The mean reduction in yield for all three experiments produced by the omission of phosphorus was 28.5 percent, for nitrogen 15.2, and for potassium 6.3. If the reductions in yields were proportional to the fertilizer requirements it might be concluded that the potato plant, under conditions similar to those in

this experiment, requires about 2½ times more nitrogen and about 5 times more phosphorus than potassium.

A high demand for phosphatic fertilizer has been also observed for such crops as tomatoes (4),[2] tobacco (3), cucumbers (6), corn (10), eggplant (9), and red beans (5), in Puerto Rico. However, sweetpotatoes, also grown on a Lares clay at Corozal, failed to show a high demand for phosphatic fertilizer (4). Sugarcane (7) and pineapples (8) have failed to respond to phosphorus applications in the same soils where the potato and other above-mentioned crops have given significant responses to such applications. Sugarcane did respond to phosphorus at Isabela on Coto clay soil. (2) In this soil the highest reduction in potato yields was also observed when phosphorus was omitted (table 4).

Potato production for all three experiments was highest when the plants were 6 inches apart in the row. The mean reduction in yield for all three experiments for the 9-, 12-, 15-, and 18-inch spacings were 15.6, 20.5, 30.3, and 38.1 percent, respectively (see table 4). The greatest reduction was observed at Aibonito.

PRACTICAL RECOMMENDATIONS

FERTILIZER

The response of the potato to fertilizer was greatest for phosphorus, less for nitrogen, and least for potassium. For the potato grown on Lares, Coto, and Juncos clays and similar soils of the Corozal, Isabela, and Aibonito areas where the respective experimental trials were performed, and in order to prevent depletion of the soils, the following fertilizer recommendations for potatoes seem to be in order:

Nitrogen: 50 to 100 pounds of N per acre.
Phosphorus: 75 to 125 pounds of P_2O_5 per acre.
Potassium: 25 to 50 pounds of K_2O per acre.

The most important item for the farmer to keep in mind is that higher rates of phosphorus than of nitrogen are needed to prevent excessive foliage growth in lieu of high yield in potatoes. The use of an unbalanced fertilizer formula by the farmer will prove to be economically detrimental.

PLANTING DISTANCE

Normally farmers in Puerto Rico plant potatoes from 12 to 18 inches apart. The results of these experiments show that the distance between plants in the row should be reduced to 6 inches.

SUMMARY

Combined fertilizer and spacing experiments with potatoes were conducted at Corozal on Lares clay soil, at Isabela on a Coto clay soil, and at Aibo-

[2] Numbers in parentheses refer to Literature Cited, p. 110.

nito on a Juncos clay soil. The experiments were planted in December 1953 and January 1954. The areas were located at different elevations with variation in soils and climate. The potato variety Kennebec, resistant to blight, was planted. The major results were:

1. Nitrogen did not consistently increase the yield of potatoes significantly.
2. Phosphorus increased the yield of potatoes most.
3. Potassium failed to increase the yield of potatoes significantly.
4. The Coto clay soil gave the highest yield increases attributable to the use of phosphorus fertilizers.
5. The 6-inch planting distance gave the highest potato yields in all three experiments.
6. The interaction between fertilizer and planting distance, or number of potato seed pieces planted per acre, was not significant. As the number of seed pieces increased there was no need for higher rates of fertilizer applications.
7. A highly significant correlation was obtained between number of potato seed pieces planted per acre and yield in all three experiments. This relationship indicates that, as the number of seed pieces increases, the yields also increase.
8. For all three experiments the mean reductions in yield caused by the omission of nitrogen, phosphorus, and potassium were 15.2, 28.5, and 6.3 percent, respectively.
9. Taking yield at 6-inch spacings as 100, the reduction in yield at 9 inches was 15.6, at 12 inches 20.5, at 15 inches 30.3, and at 18 inches 38.1 percent.

RESUMEN

Se llevó a cabo una investigación sobre los abonos y las distancias en cuanto a la siembra de papas en un suelo Lares arcilloso en Corozal, en un suelo Coto arcilloso en Isabela y en un suelo Juncos arcilloso en Aibonito. Las siembras de estos experimentos se efectuaron en diciembre de 1953 y en enero de 1954.

Las áreas seleccionadas para el establecimiento del trabajo de investigación variaron en elevación, suelos y clima. Se usó la variedad de papa Kennebec, que es resistente al rizón. Los resultados sobresalientes del estudio fueron los siguientes:

1. El uso del nitrógeno no siempre aumentó los rendimientos significativamente.
2. El uso del fósforo produjo los aumentos mayores en los rendimientos.
3. No se obtuvo aumentos significativos en los rendimientos con el uso de la potasa.
4. El uso del fósforo causó los mayores aumentos en la arcilla Coto.

5. Las siembras a 6 pulgadas entre plantas en la hilera produjeron los rendimientos más altos en cada uno de los tres experimentos.

6. La interación entre los abonos y las distancias de siembra no fué significativa. Tal parece que la cantidad de abono a aplicarse al suelo en cuanto a la papa, no tiene que aumentarse necesariamente en la práctica, si la distancia de siembra se acorta.

7. Se obtuvo una correlación altamente significativa entre el número de plantas por acre y el rendimiento. La relación indica que el rendimiento aumenta proporcionalmente según se aumentael número de plantas.

8. Los rendimientos se redujeron un 15, un 28 y un 6 porciento cuando se omitieron en el abono, el nitrógeno, el fósforo y la potasa, respectivamente.

9. Si se toma la distancia de 6 pulgadas como 100, el porciento de reducción en los rendimientos fué 15.6 para la distancia de 9 pulgadas; 20.3 para la de 12; 30.3 para la de 15, y 38.1 para la de 18.

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RESEARCH NOTES

SUSCEPTIBILITY OF SOME VARIETIES OF MELONS TO THE CUCURBIT VIRUSES PRESENT IN PUERTO RICO

Melons have never been grown in Puerto Rico on commercial scale either for local consumption or for the export market. The possibility remains of growing this valuable and delicious fruit for the winter market in the States where it would certainly command good selling prices.

Before this could be done, however, a variety of melons must be found well adapted to our growing conditions, of good shipping qualities, and at the same time resistant to the prevalent diseases of this crop in the Island. Riollano[1] at the Isabela Substation has reported the Smith Perfect variety as good for export as well as for the local market. More recently Robbins[2] at the Vega Alta hydroponic farm successfully grew several melon varieties: Georgia, X-100 and Fajardo, the two most promising being Georgia and especially X-100.

Since Adsuar and Cruz Miret[3] found that cucurbits in Puerto Rico are commonly affected by two distinct viruses, A and B, it was considered of interest to test the above-mentioned melon varieties in order to determine their resistance to these two viruses. Seeds of the varieties Smith Perfect, Georgia, Fajardo, and X-100 were kindly supplied by Robbins and Riollano. The plants were inoculated when about 15 days old, using the methods previously described.[3] The two viruses were inoculated separately on each variety.

The results of the inoculations demonstrated that the melon varieties tested were susceptible to the two viruses attacking cucurbits in Puerto Rico.

J. Adsuar
Department of Plant Pathology

A MOSAIC DISEASE OF THE YAM, DIOSCOREA ROTUNDATA, *IN PUERTO RICO*

A mosaic disease affecting yams, *Dioscorea rotundata* Poir, was first observed in the Caguana county near the town of Utuado in August 1952. The plantation visited consisted of around 7 acres, all the plants in which were totally affected. It has been observed in other parts of the Island since.

The most important symptoms of the disease in the field consist of yellow

[1] Riollano, A., A new variety of muskmelon for Puerto Rico, *Amer. Soc. Hort. Sci.* **42** 574, 1943.

[2] Robbins, S. R., personal communication, 1954.

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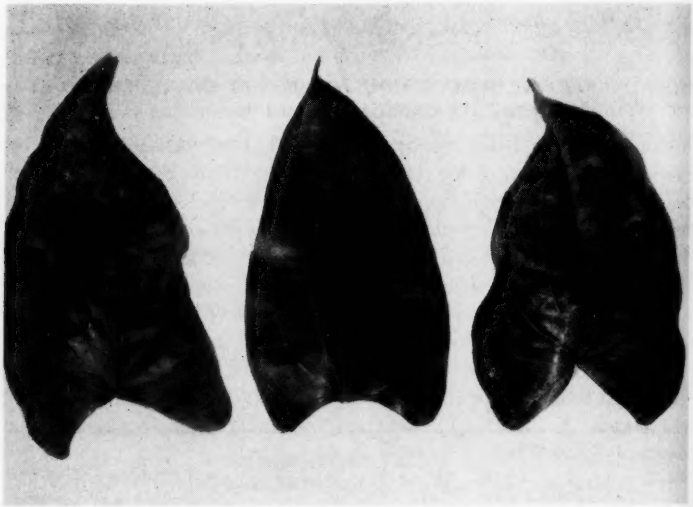

FIG. 1.—Leaves of yams affected with the mosaic with healthy leaf at center.

and dark green patches on the leaves (fig. 1) accompanied by a slight distortion of the leaf lamina. Not all the leaves exhibit the mosaic, however, and in the majority of cases only about half of the leaves are affected, the others presenting the glossy green color characteristic of the healthy plant. Healthy plants are noticeably larger than diseased ones.

The virus is transmissible to yam, tobacco, pepper, and cucumber. It can be transmitted to susceptible plants with considerable difficulty by rubbing the infectious sap with the aid of carborundum and occasionally by grafting (tuber grafting) in the case of yams. The best method of transmission from yam to yam is by needle pricking through an infected leaf wrapped around a stem or petiole of a healthy yam. After successful establishment on tobacco, the virus is more easily transmissible by sap inoculation to tobacco and from tobacco to pepper and cucumber.

The disease is transmitted through the tubers of infected yam plants. Roots from apparently healthy yams are capable of producing diseased plants.

The insect vector of the disease is not known.

The virus withstands exposure for 10 minutes at 50° C., but is inactivated at 60° C. It retains infectivity at a dilution of 1:1000 but not at 1:10,000. Infectivity of the virus in expressed juice is lost before 24 hours at room temperature. When infected leaves are air-dried in the laboratory they retain their infectivity for 10 days but lose it after 24 days. The virus is still infectious after 1 month at −5° C.

Besides the yam, *Dioscorea rotundata*, the virus infects *Cucumis sativus*, *Nicotiana tabacum*, and *Capsicum frutescens*. We have not been able to determine the susceptibility of other varieties or species of yams to the virus.

Cook[1] has reported a mosaic disease of yam (*Dioscorea* sp.) from Puerto Rico and Deighton[2, 3] has described a similar disease from Africa. As far as we have been able to determine those are the only two viruslike diseases occurring in yams so far reported. The disease dealt with in this note is probably similar to, if not identical with the ones observed by Cook and Deighton, but unfortunately comparison is impossible as those investigators did not study the causal viruses concerned.

J. Adsuar
Department of Plant Pathology

A DISEASE OF TOMATO IN PUERTO RICO RESEMBLING THE BRAZILIAN CURLY TOP OF TOMATOES

A disease of tomatoes caused by virus infection has been observed for the past several years in the Island of Puerto Rico. The disease is known locally as "tisis"; it occurs the year round. Our observations show that the field incidence of the disease fluctuates from a few cases up to 12 percent, although it usually remains very low. Infected plants are characterized by severe stunting and marked stiffening and bronzing of stem and petioles (fig. 1, A). There is a downward curling of tips and margins of the leaflets which turn yellow and remain small. Affected plants fail to produce fruits and in many cases wither and die.

Transmission experiments have shown that the disease is not transmitted by juice-inoculation methods but is readily transmitted by grafting. Experiments involving mechanical inoculation with the aid of carborundum and the addition of $NaSO_3$ to the extracted juice have failed to reproduce the disease on the following plants: *Lycopersicum esculentum* L., *Cucumis sativus* L., *Capsicum frutescens* L., *Nicotiana glutinosa* L., *and Phaseolus vulgaris* L.

Typical symptoms were produced in about 1½ months by grafting infected tomatoes on *Lycopersicum esculentum* L., *and Datura stramonium*. *D. stramonium*, (fig. 1, B) grafted with diseased tomatoes showed symptoms similar to those produced on infected tomato plants. Clearing or yellowing of small veins was followed by wrinkling and downward curling of leaves. Diseased plants became stunted, but there was no bronzing of stems and petioles. Similar grafts induced no symptoms on plants of *Solanum tuberosum* L., *N. tabacum* L., and *S. nigrum* L. Attempts failed to transmit the virus by means of the leafhopper *Agallia albidula* Uhl.

[1] Cook, M. T., Ann. Rept. Agric. Expt. Station, Río Piedras, P. R. 1935–36, 1937.
[2] Deighton, F. C., Rept. Dept. Agric. S. Leone, 1935, pp. 22–6, 1936.
[3] ——. Rept. Dept. Agric. S. Leone, 1937, pp. 45–7, 1938.

A B

FIG. 1.—Tomato plant (A) and *Datura stramonium* (B) showing symptoms of "tisi

The virus occurring on tomatoes in Puerto Rico bears a striking sym tomatological resemblance to the curly top viruses on tomatoes report from Brazil[1, 2]. One of these viruses, the *brasiliensis* variety, is transmitt by the leafhopper, *Agallia albidula* Uhl., and has a wide host range. T other virus, the *solanacearum* variety, is transmitted by the leafhoppe *Agalliana ensigera* Oman and *Agallia sticticollis* Stahl, and its host range much narrower.

The fact that we have not been able to transmit our virus by means *A. albidula* might indicate that it is related to the *solanacearum* variety curly top which is transmitted by *A. sticticollis*, as reported by Costa (2 It remains to be seen, whether *A. sticticollis*, an insect which is rarely fou on tomatoes under our conditions, is also the vector of our virus. On t other hand, it is interesting to notice the resistance of *S. nigrum* to our t mato virus, a plant which Costa found to be one of the few hosts suscep tible to the *solanacearum* variety of Brazilian curly top. Therefore, whethe the "tisis" of tomato in Puerto Rico is related to varieties of tomato curl top found in Brazil cannot be determined definitely until further studie are made.

José Adsur
Department of Plant Patholog

[1] Bennett, C. W., and Costa, A. S., The Brazilian curly top of tomato and tobacc resembling North American and Argentine curly top of sugar beet, U.S.D.A. *J. Ag Res.* **78** 675–93, 1949.

[2] Costa, A. S., Further studies on tomato curly top in Brazil, *Phytopath.* **42** 396–40 1952.